THE

DIAGNOSIS and TREATMENT OF CARDIOVASCULAR DISEASE

Edited by

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This book

is gratefully dedicated

by its editor

to

SIR THOMAS LEWIS

AND

DR. GEORGE W. NORRIS

with deep appreciation of their

friendship, instruction and wise

counsel

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PREFACE

Although there have been numerous books written on heart disease and some monographs on peripheral vascular disease yet no complete volume including a detailed discussion of the whole subject of cardiovascular disease has appeared This is the reason for this work

The problem of cardiovascular disease has become so large and so complicated that it appears to me impossible for one man to write a completely satisfactory book on this subject I have been unusually fortunate in the cooperation of the outstanding authorities in cardiovascular disease in this country and whatever value this work has is almost entirely due to them

Since there are in all 56 contributors and since the various problems of cardiovascular disease are so closely related there has been necessarily some overlapping In my opinion this is justifiable since it is seldom that two authorities have exactly the same ideas concerning any cardiovascular problem

Although this work covers the entire subject of cardiovascular disease it has not been done in an encyclopedic form There are comparatively few cases in which diphtheria and other acute infections—except rheumatic fever—permanently damage the heart so that this subject has been omitted There is no chapter on the prognosis in different types of cardiovascular disease since this subject is considered in the various chapters.

Although I hesitate to mention any of the chapters specifically yet since it is *becoming increasingly evident that all internists should have* an understanding of electrocardiography I should like to call attention to the chapter on this subject by Bellet and McMillan Any physician can find an almost exact duplicate for most electrocardiograms amongst the figures in this chapter and by following the text with its description in simple language may easily make a conservative and accurate interpretation of such electrocardiograms

There has been a determined effort to secure many illustrative case histories since this is recognized as a practical method of presenting the necessary procedures for diagnosis and effective treatment

FOREWORD

By Sir Thomas Lewis

Within living memory our knowledge both of maladies of the heart and, more recently of diseases of the peripheral circulation, has profoundly changed it has become far more exact and far more comprehensive than formerly it continues to grow rapidly These changes have been brought about chiefly in the English speaking countries, and not least in the United States of America The brilliant list of American authors of the present contents includes a score of names known in every part of the world where cardiovascular diseases have been intensively studied they are known for the solid contribution of those who bear them to their subject Rarely before has such a number of authoritative writers combined to place its views of a branch of medicine on record and never before of cardiovascular disease it is a guarantee to the reader that he is in direct or close contact with all the fountains of modern knowledge, the most important guarantee perhaps that any reader can be given

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INTRODUCTION TO DISEASES OF THE CARDIOVASCULAR SYSTEM

By Howard B. Sprague, M.D. and Paul D. White, M.D.

One of the most useful contributions to progress in the study of disease is a proper definition of terms and a classification of diagnoses based upon a complete analysis of the various syndromes. In cardiovascular disease this has proved most practical by describing the diagnosis of each case from the standpoint of the etiological factor responsible for the disease, the changes in the structure of the tissues or organs involved, the disturbances of their function, and the interference with bodily activity by the disease. By including in this way a fourfold explanation of the status of the heart or blood vessels we avoid vague categories of the past which have described only one aspect of the disease such as "mitral regurgitation," "auricular fibrillation," "dropsy," or "intermittency of the pulse." Therefore for satisfactory diagnosis of the condition of a patient suffering from heart disease at least one subheading from each of the four main divisions of the following classification should be included.

A. ETIOLOGICAL

1. **Congenital Cardiovascular Defect.** This is an aberration of development thought to be due generally to faulty germ plasm and rarely to intrauterine infection.

2. **Rheumatic Infection of Heart or Blood Vessels.** The etiologic agent of the rheumatic infection is unknown. It is in general a disease of cold, moist climates, appearing first in childhood, in the lower economic groups of the population. Some form of streptococcus appears to play a part in the disease but has not been proved to be the primary virus. The commonest precipitant of an attack is an upper respiratory infection

(*a*) Rheumatic fever (polyarthritis) Inflammatory rheumatism

(*b*) Sydenham's chorea St Vitus dance

(*c*) Indefinite systemic type (growing pains tonsillitis or pharyngitis gastrointestinal disorders epistaxis pulmonary inflammation and cutaneous or subcutaneous manifestations such as nodules erythema multiforme and purpura)

3 **Bacterial Infection** (Specify bacterium if possible) In this group are classified all cases in which an infective agent other than that of rheumatism or syphilis has produced an inflammatory reaction in pericardium myocardium or endocardium Diphtheria unless very mild or early recognized and properly treated tends to cause extensive and sometimes fatal myocardial necrosis Most infectious diseases do very little actual damage to the heart and hence terms like the influenza heart and the typhoid heart are really misnomers it is true of course that any very severe infection may affect the heart by toxic action or even cause mild structural changes just as it affects any tissues in the body—such effects are sometimes noted in patients dying of infectious disease Rare types of myocarditis including tuberculous that due to trichinae periarteritis nodosa and so-called focal or disseminated interstitial lesions (of unknown etiology but probably infectious) belong in this category also as do certain infections like the Brazilian trypanosomiasis (Chagas disease) that are limited to certain parts of the world The majority of cases of nonrheumatic and nontuberculous pericarditis both acute and chronic (including the constrictive type) are obviously of infectious origin even though it is rarely possible to identify the bacterium responsible In general however endocardial infection is most common of this the two following types may usually be differentiated

(*a*) *Acute* (Streptococcus hemolyticus staphylococcus pneumococcus gonococcus Bacillus influenzae meningococcus etc)

(*b*) *Subacute* (usually nonhemolytic—Streptococcus viridans—type of endocarditis but including other infections such as tuberculosis of the pericardium)

Although the difference between the acute and subacute types of bacterial endocarditis is largely a matter of the duration of the disease from the onset to what is practically always a fatal termination the types differ also in the fact that the acute type is usually a complication of an acute septicemia and often affects previously uninjured hearts whereas

the subacute type is much more likely to attack heart valves damaged by rheumatism and to have an unexpected and insidious onset the latter (subacute) type also affects hearts with congenital defects and arterio venous communications in the great vessels such as patent ductus arteriosus or even peripheral arteriovenous fistulae

4 Syphilis This affects most commonly the first portion of the aorta less often the heart muscle and the arteries of both greater and lesser circulations

5 Thyroid Disease (*a*) *Thyrotoxicosis* Long continued over activity of the thyroid gland may result in fatigue of the heart from tachycardia and the onset of auricular fibrillation The hypothesis of a true toxic effect from the abnormal secretion of the gland is unproved

(*b*) *Hypothyroidism* Myxedema has been held responsible in rare cases for marked cardiac dilatation and weakness and commonly for low voltage curves by electrocardiograph Cases treated satisfactorily by *thyroid medication have sometimes shown striking decrease in heart size* by x rays and always improvement in the electrocardiographic complexes

6 Hypertension (*a*) *Systemic* Prolonged hypertension results characteristically in cardiac hypertrophy chiefly of the left ventricle and finally failure from fatigue of the muscle with or without the complica tion of coronary arteriosclerosis

(*b*) *Pulmonary* Factors increasing the tension in the pulmonary circuit such as mitral stenosis emphysema pulmonary fibrosis and primary disease of the pulmonary vessels (endarteritis obliterans) may cause hypertrophy and failure of the right ventricle (chronic cor pulmonale) However the commonest cause of right heart failure is pulmonary hypertension dependent upon failure of the left ventricle from factors responsible for strain on this chamber The heart failure of *acute rheumatic carditis* is preponderantly right ventricular due prob ably to the relative weakness of this ventricle as compared to the left in the presence of a diffuse myocardial reaction In some instances acute rheumatic changes in the lung may be a factor in producing pulmonic hypertension

The term *chronic cor pulmonale* is routinely reserved for cases of right ventricular hypertrophy secondary to primary involvement of the lungs and pulmonary blood vessels and is *not applied to cases of right*

ventricular enlargement due to mitral stenosis or to chronic failure of the left ventricle

Acute cor pulmonale is a condition of sudden right ventricular dilatation and failure due to abrupt rise in pulmonary vascular tension of which the classical example is massive pulmonary embolism

7 **Atheroma and Sclerosis** (*a*) *Coronary Disease* Degenerative changes of the coronary vessels are primarily responsible for the common symptom of angina pectoris and their further extension for coronary thrombosis with myocardial infarction Slower occlusion with the development of compensatory circulation may result in electrocardiographic changes or evidence of cardiac weakness or may cause no symptoms or signs at all

(*b*) *Valvular Sclerosis* The sequel to atheroma or calcareous disease of the valves (chiefly mitral or aortic) results in murmurs of regurgitation or obstruction dependent upon the degree of the process It is not known how often such changes are preceded by infection of the valves

(*c*) *Peripheral Arterial Atheroma and Sclerosis* A cause of vascular but not of cardiac disease

(*d*) *Medial Cystic Necrosis* This condition is a degenerative process in the media of the aorta unrelated to ordinary atheroma and is the substrate for dissecting aneurysm Rupture of the intima in hypertensive subjects results in a splitting of the adventitia from the intima as the blood dissects through the cystic media

8 **Neoplasm (Primary or Secondary)** Most neoplasms of the heart are secondary either to direct extension from the lung and pericardium or to metastasis Rarely primary tumors occur A relatively nonmalignant type—myxoma of the auricle—can produce signs suggesting mitral stenosis and emboli from the growth may produce a syndrome simulating subacute bacterial endocarditis

9 **Trauma** Valve rupture gunshot and stab wounds and crushing injuries of the chest (such as the steering wheel injury) are included here

10 **Irritability** (*a*) *Neurocirculatory Asthenia* Soldier s heart Effort Syndrome This is a common disorder of cardiovascular action in which symptoms of fatigue appear without adequate cause No organic disease can be discovered in the heart The fundamental cause is still obscure

(*b*) *Arrythmias* of unknown (nervous) origin

11. Cardiac Neurosis: This is a mental attitude toward cardiac disease, with or without organic or functional heart disorder, characterized by apprehension, and related to anxiety states, but rarely to hysteria or other psychoses The complaints are not consistent with the cardiac findings, or are exaggerated beyond the normal by fear

12. Miscellaneous Causes· (*a*) *Anemia* With marked lowering of hemoglobin from primary or secondary anemia, there are symptoms of breathlessness and tachycardia, with cardiac dilatation and often murmurs of functional type Changes in heart muscle (tigering) also may occur

(*b*) *Obesity and Fatty Infiltration, "Fatty Heart'* The symptoms of cardiac type of obese individuals are largely due to fatigue and 'effort syndrome,' but in certain cases large fat deposits in or about the myocardium may perhaps embarrass its action

(*c*) *"Athlete's Heart'* It is doubtful if an average normal heart can be injured by physical activity, but in certain cases prolonged exertion, as in long distance running or ski racing, results in cardiac hypertrophy Much of what is attributed to athlete s heart is due to nervous reactions from competitive effort or to some other kind of heart trouble

(*d*) *Deficiency Diseases* In dietary deficiency diseases, such as rickets and beriberi, cardiac pathology has been demonstrated It is now recognized that vitamin B_1 deficiency is not infrequently seen in the Occident, mainly in alcoholics with faulty dietary habits and in intestinal diseases A type of cardiac failure, with electrocardiographic changes, responding rapidly to B_1 administration, has been described Excess of such food factors as cod liver oil and irradiated ergosterol has, on the other hand been shown experimentally to injure the heart

(*e*) *Senile* In the absence of obvious coronary disease, advanced age may be associated with changes (dehydration pyknosis, etc) of cardiac muscle which attend the general weakening of the body and make it less able to withstand such strains as infection and surgery

(*f*) *Other Conditions* There are many states of ill health of all kinds which, usually in very minor degree may depress or irritate the heart and circulation Their number is legion and include not only most of the infectious diseases but also diseases of the kidneys, liver, lungs, and central nervous system It seems unnecessary and actually unwise to classify them as types of heart disease.

13 **Unknown** Certain obscure cardiovascular conditions still exist which it is only possible to call of unknown cause They should be classified in this way to stimulate further investigation Such hearts appear dilated often preponderantly on the right side but show no valvular or coronary disease nor recognizable specific myocardial changes It is believed that syphilis may be the cause in some instances In a few careful microscopic study of the small pulmonary vessels reveals obstruction sufficient to classify them as cases of chronic cor pulmonale

14 **Possible Heart Disease** Cases in which signs or symptoms exist which are not explicable by present methods should until capable of classification be called possible heart disease

15 **Potential Heart Disease** This term is limited almost entirely to patients who have had rheumatic infections but who up to the time of examination have shown no cardiovascular disease

B STRUCTURAL

1 **Displacement of Heart**
- (*a*) Congenital (dextrocardia or ectopia cordis)
- (*b*) Acquired mechanically as secondary to pulmonary collapse or fibrosis pneumothorax pleural lesions or thoracic tumors or aneurysms

2 **Change in Size of Heart as a Whole or of Individual Chambers**
- (*a*) Atrophy of heart.
- (*b*) Hypertrophy
  - (1) Ventricular (left right)
  - (2) Auricular (left right)
- (*c*) Dilatation of heart
  - (1) Ventricular (left right)
  - (2) Auricular (left right)

3 **Myocardial Disease (Acute or Chronic)**
- (*a*) Congenital defects.
- (*b*) Inflammation (diffuse or localized)
- (*c*) Fibrosis.
- (*d*) Fatty change (infiltration or degeneration)
- (*e*) Infarction (ischemic necrosis)
- (*f*) Calcification.
- (*g*) Neoplasm.

4 **Cardiac Aneurysm**

5 Cardiac Rupture

6 Congenital Anomalies of Cardiac Chambers, Septa or Great Vessels

(a) Auricular septal defect

(b) Ventricular septal defect *

(c) Trilocular heart

(1) With one auricle

(2) With one ventricle

(d) Bilocular heart (one auricle and one ventricle)

(e) Common arterial trunk

(f) Transposition of the great arteries.

7 Endocardial Disease (Acute or Chronic, Involving Valves, Mural Endocardium, Papillary Muscles, or Chordae Tendineae)

(a) Congenital defects

(b) Inflammation

(c) Sclerosis

(d) Valvular deformity

(1) Mitral—insufficiency or stenosis

(2) Aortic—insufficiency or stenosis

(3) Tricuspid—insufficiency or stenosis

(4) Pulmonary—insufficiency or stenosis

8 Pericardial Disease (Acute or Chronic)

(a) Congenital defects

(b) Inflammation

(c) Effusion (state type of fluid)

(d) Adhesions

(1) Without constriction of the heart

(2) With constriction of the heart (Pick s disease)

(e) Calcification

(f) Pneumopericardium

(g) Neoplasm

9 Vascular Disease

(a) Coronary vessels

(1) Congenital anomaly

(2) Inflammation

* When a ventricular septal defect is combined with pulmonary stenosis dextroposition of the aorta and right ventricular enlargement the condition is known as the *Tetralogy of Fallot* the commonest type of the cyanotic congenital heart patient

- (3) Sclerosis
- (4) Aneurysm
- (5) Embolism
- (6) Thrombosis
- (7) Periarteritis nodosa
- (8) Rupture

(*b*) Aorta

- (1) Congenital anomaly, especially coarctation and right aortic arch
- (2) Inflammation
- (3) Sclerosis
- (4) Dilatation or aneurysm
- (5) Embolism
- (6) Thrombosis
- (7) Dissecting aneurysm (nonluetic)
- (8) Rupture

(*c*) Pulmonary artery and branches

- (1) Congenital anomaly
- (2) Inflammation
- (3) Sclerosis
- (4) Dilatation or aneurysm
- (5) Embolism
- (6) Thrombosis
- (7) Endarteritis obliterans

(*d*) Peripheral arteries

- (1) Congenital anomaly
- (2) Inflammation
- (3) Sclerosis
- (4) Dilatation or aneurysm
  - (a) Luetic
  - (b) Mycotic
  - (c) Traumatic
- (5) Embolism
- (6) Thrombosis (thromboangiitis obliterans)
- (7) Periarteritis nodosa

(*e*) Diseases of veins, capillaries and lymphatics

10 Undiagnosed Cardiovascular Disease

C FUNCTIONAL

I. Normal Mechanism of the Heart Beat and Its Disturbances: This section includes changes in the activity of the heart which, in many instances, can be accurately analyzed only by the electrocardiograph

(a) *Normal Rhythm and Changes of Vagosympathetic Origin* Under this heading are the disturbances which occur from an exaggeration of the activity of the nerves responsible for accelerating or slowing the pacemaking function of the sinoauricular node

(1) Normal rate—usually 60 to 80 per minute

(2) Sinoauricular tachycardia This is the response to such factors as exertion, emotion, fever, hemorrhage, asphyxia, thyrotoxicosis cardiac failure or infection, vagal paralysis or sympathetic stimulation which results in a rapid heart rate under control of the normal pacemaker The rate is between 100 and 200 per minute

(3) Sinoauricular bradycardia This is also a normal response of the heart by slowing to such factors as rest, convalescence, pregnancy puerperium, jaundice, nausea, or vagal stimulation The rate is under 50 per minute Increased intracranial pressure may result in bradycardia, and carotid sinus pressure can produce marked cardiac slowing without auriculoventricular block Acetylcholine and its derivatives and ipecac are the most active agents in vagal stimulation

(4) Sinus arrhythmia During respiration there is a normal reflex change in vagosympathetic tone which results in an inspiratory quickening and expiratory slowing of the heart called sinus arrhythmia Rarely this sinus arrhythmia is not related to respiration In patients in the sclerotic age a high degree of sinus arrhythmia is an abnormal finding and suggests obstruction of the blood supply to the sinoauricular node

(5) Sinoauricular standstill With marked vagal hypertonia the sinoauricular node may be so depressed that at intervals it does not initiate an impulse Thus the node is said to be blocked or to be at a standstill

(6) Wandering pacemaker In certain cases the point of impulse formation in the auricle may be shown by electrocardiograph to change its position physically or irregularly This appears as an alteration of the auricular (P) wave, usually a lowering flattening or inversion

(7) Ventricular escape (auriculoventricular nodal escape) The impulses arriving from the sinoauricular node may be so much slowed

or the auriculoventricular node may be so irritable that the pacemaker in the A-V node may "escape" and cause the ventricle to beat at the same time as the auricles or to precede them.

(8) Auriculoventricular nodal rhythm. If the auriculoventricular node becomes irritable or the sinoauricular node much depressed, the former may become the pacemaker for the whole heart and the ventricles may beat synchronously with the auricles or just before or after.

(*b*) *Disturbances of the Pacemaking Function:* (1) Premature beats. Irritable foci in various parts of the heart may initiate single or multiple beats at rates faster than the sinoauricular node. The origin of these beats may be:

(a) Auricular
(b) Ventricular
(c) A-V Junctional
(d) Unknown

(2) Paroxysmal tachycardia. If the irritable focus produces impulses in a connected series, a paroxysm of rapid beats may occur. These may also be:

(a) Auricular
(b) Ventricular
(c) A-V Junctional
(d) Unknown

(3) Auricular flutter. This disturbance is apparently due to a "circus movement" or wave of excitation circulating about the great veins at the base of the heart and sending off impulses regularly to the rest of the heart at a speed of 200 to 400 per minute. A regular grade of block usually exists between the auricles and ventricles, generally 2:1. The condition may be:

(a) Paroxysmal
(b) Permanent

(4) Auricular fibrillation This rhythm is a more advanced stage of the circus movement than auricular flutter, and more rapid (average rate in the auricle 300 to 500 per minute) and irregular. An irregular degree of block exists between auricles and ventricles:

(a) Paroxysmal
(b) Permanent

(5) Ectopic auricular rhythms of other nature than paroxysmal tachycardia, auricular flutter, or auricular fibrillation. Such rhythms are of obscure mechanism and are relatively rare.

(6) *Ventricular fibrillation.* This rhythm *is not* compatible with life for more than a very short time and has been rarely proved by electrocardiogram, although it may perhaps be a common terminal state of the heart muscle. Its mechanism is apparently similar to that in the auricle in auricular fibrillation. A more common rhythm, although also rare, is a more regular type of ventricular flutter, apparently a state intermediate between ventricular paroxysmal tachycardia and fibrillation. It may occur in attacks associated with syncope and carries a grave prognosis.

(c) *Disturbances of Conduction*

(1) Auriculoventricular block.

(a) Partial.

1. Prolonged conduction time (over 0.2 second and in young children over 0.15 second) between auricle and ventricle.
2. Occasional dropped beats (failure of the ventricle to respond to every auricular impulse).
3. High-grade block (such as 2 : 1, 3 : 2, 3 : 1 and 4 : 1).

(b) Complete. Idioventricular rhythm. The auricles and ventricles are entirely dissociated, the ventricles beating at a rate usually between 30 and 40.

(2) Intraauricular block (produced in experimental animals but not clearly demonstrated yet in man).

(3) Intraventricular block.

(a) Incomplete bundle branch block.

(b) Bundle branch block (right or left).

(d) *Abnormal Electrical Axis Deviation (Right or Left).* Deviation of the electrical axis to the right (inverted Q R S in Lead I and upright Q R S in Lead III) is found in the vertical type of heart as in tall thin individuals with low diaphragms and in persons having right ventricular enlargement (due to mitral stenosis, congenital pulmonary stenosis and cor pulmonale). Deviation to the left (upright Q R S in Lead I and inverted *Q R S in Lead III*) is found in those with the

horizontal type of heart or with left ventricular enlargement (due to hypertension aortic regurgitation or stenosis or myocardial infarction)

(e) *Abnormalities of the S T Segments and T Waves* The most important of all electrocardiographic changes are those of displacement of the S T segments and inversion of the T waves They indicate toxic acute degenerative inflammatory or ischemic changes in ventricular muscle and are found most commonly in cardiac infarction

II Faulty Cardiac Efficiency

(a) *Ventricular weakness* with or without obvious congestion (congestive failure)
  (1) Left with or without pulsus alternans
  (2) Right

(b) *Ventricular ischemia* due to coronary insufficiency with or without angina pectoris

(c) *Auricular weakness or failure* especially in auricular fibrillation

(d) *Valvular incompetency*
  (1) Mitral
  (2) Aortic
  (3) Tricuspid
  (4) Pulmonary

(e) *Adams Stokes syndrome,* due to heart block with ventricular standstill

III Faulty Vascular Efficiency
  (a) *Hypertension*
  (b) *Hypotension*
  (c) *Vascular spasm* (cerebral crises Raynaud s disease)
  (d) *Vascular dilatation* (vasomotor shock)

IV Faulty Cardiovascular Efficiency
  (a) Combination of II (Faulty cardiac efficiency) and III (Faulty vascular efficiency)
  (b) *Coronary insufficiency* with or without angina pectoris
  (c) *Neurocirculatory asthenia* (effort syndrome or the soldier s heart)

D CARDIOVASCULAR ABILITY

1 Patients with organic heart disease able to carry on ordinary physical activity without discomfort

2. Patients with *organic heart disease unable to carry on ordinary* physical activity without discomfort:

(*a*) Activity slightly limited.

(*b*) Activity greatly limited.

3. Patients with organic heart disease and with symptoms or signs of heart failure when at rest, unable to carry on any physical activity without discomfort.

Examples of the application of this simple and useful classification are the following:

Case 1 Boy of 8 years Congenital heart disease with the tetralogy *of Fallot, normal rhythm and greatly limited activity*

Case 2 Woman of 28 years Rheumatic heart disease acute and chronic, with mitral stenosis, auricular fibrillation, and slightly limited activity.

Case 3 Woman of 35 years Irritable normal heart with paroxysmal tachycardia, neurocirculatory asthenia and cardiac neurosis, fearful but able to carry on normal activity

Case 4 Man of 45 years Cardiovascular syphilis with aneurysm of the ascending aorta, aortic regurgitation, congestive failure, unable to carry on any effort

Case 5 Woman of 58 years Hypertensive heart disease, slight cardiac enlargement, able to carry on normally

Case 6 Man of 65 years Coronary heart disease with acute occlusion due to thrombosis, myocardial infarction at the apex of the left ventricle, ventricular premature beats, a complete invalid *pro tem*

CHAPTER II

CONGENITAL CARDIAC ABNORMALITIES

By MAUDE E. ABBOTT, M.D., LL.D.

Synonyms: Congenital cardiac disease; congenital diseases of the heart; cardiovascular anomalies of congenital origin; congenital cyanosis; cyanopathia; morbus caeruleus; blue disease.

Definition: Conditions in which, through arrest of development or disease occurring in intrauterine life, alterations in the anatomical structure of the heart and great vessels exist, which lead in the majority of cases to irregularities in the circulation, producing (*a*) cardiovascular strain, or (*b*) interference with proper aeration by an anomalous shunt of venous blood into the arterial stream by way of a defect, or by increasing deoxygenation in the capillaries, or by a combination of both these factors. In the latter events the symptom-complex of congenital cyanosis appears as soon as the "threshold-value" of raised oxygen-unsaturation is reached, and the characteristic picture of morbus caeruleus develops in all those cases in which these abnormal conditions of the circulation become permanently established.

Varieties: According to the clinical features presented and the *structural changes underlying these, the following types may be distinguished:*[1]

I. *Acyanotic Group:* These are the cases in which *no abnormal communication* exists between the venous and arterial streams but in which the mechanical interference with the circulation introduced by the anomaly makes this the seat or point of origin of *cardiovascular strain.* In this category should be included: The left-sided valvular stenoses or insufficiencies, anomalies of semilunar or auriculoventricular cusps, coarctation and hypoplasia of the aorta, primary congenital hypertrophy, congenital rhabdomyoma, pericardial defect, anomalous septa, ectopia cordis abdominalis (which cases may and do survive into adult life).

congenital arteriovenous aneurysm anomalies of the aortic arch and its branches of the pulmonary artery and of the great venous trunks

II *Cyanose Tardive* Cases of *arteriovenous shunt* with *possible* temporary or late *reversal of flow*, *cyanosis absent* except as a *transient* or *terminal* phenomenon These are *Localized uncomplicated defects* of the *interauricular, interventricular* or *aortic septa, patent foramen ovale* and *ductus arteriosus* Here the pressure being physiologically higher on the left or systemic side of the defect arterial blood passes from left to right through the defect and no cause for cyanosis exists until through the onset of pathological conditions in the right heart or lungs in later postnatal life the relative pressure on either side of the defect changes and that in the pulmonary circulation and right heart rises this causes a reversal of the direction of the shunt which now passes from right to left through the defect and becomes venous arterial in character resulting in the appearance of the phenomenon of so-called late cyanosis first described by Bard and Curtillet[2] as characteristic of the clinical picture of patent foramen ovale

III *Cyanotic Group (true Morbus Caeruleus)* Cases of *permanent venous-arterial shunt* and *right sided valvular lesions* with or without septal defect These are usually grave and complicated anomalies in which a large volume of venous blood passes continuously into the arterial stream by way *of the defect resulting in the early onset of per*sistent and progressively increasing cyanosis with clubbing and other attendant phenomena Such are Complete absence of the cardiac or ventricular septa (cor biloculare or triloculare) persistent truncus arteriosus pulmonary and tricuspid stenosis with closed ventricular septum but patent foramen ovale *pulmonary stenosis with ventricular* septal defect and dextroposition of the aorta (tetralogy of Fallot) pulmonary tricuspid aortic and mitral atresias (in all of which a ventricular septal defect or patent foramen ovale is present permitting the circulation to be carried on and giving passage to a permanent venous arterial shunt) *transposition or reversed torsion of the arterial trunks* *pure* congenital dextrocardia (always complicated by grave cardiac anomalies) etc A few cases are recorded of pulmonary and tricuspid stenosis *with closed septa* In these cyanosis when it appears must be due to increased deoxygenation in the capillaries

IV *Cases of No Clinical Significance* In addition to the above types of congenital cardiac abnormalities all of clinical import a fourth group must be differentiated which is of purely academic interest but must be recognized as such These are the cases of no clinical significance either because (*a*) the cardiac deformity is of so grave a nature that life cannot be carried on as in acardiac monsters ectopia cordis cervicalis (nonviable) etc or (*b*) because the anatomical changes of the defect are not such as to impair the efficiency of the heart or to bring its structures into abnormal relations with the rest of the cardiovascular tree This is the case in mirror picture dextrocardia with complete situs inversus viscerum bifid apex double mitral ostium persistent left superior cava etc

ETIOLOGY AND PATHOGENESIS

By far the commonest cause of congenital cardiac abnormalities is *arrest of development of the heart* occurring in the great majority of the cases between the *fifth and eighth weeks of fetal life*, arrest before this time usually rendering the embryo nonviable and closure of the cardiac septa occurring at the end of the latter date The graver anomalies of the cyanotic group probably take origin in the earlier part of this period (fifth and sixth weeks) when division of the atrio ventricular canal and truncus arteriosus is proceeding coincidently with shifting and rotation of these parts upon themselves in the median axis of the heart and while involution of the primitive bulbus cordis and truncus arteriosus is taking place Interference with growth at any point at this critical time is liable to give rise to further anatomical changes of a compensatory nature rendering the end result as seen in the fully developed heart after birth at first sight bizarre and confusing Closer observation however shows that the conditions presented are merely adaptations of structure for the maintenance of the circulation under the anomalous conditions imposed by the defects which follow simple mechanical and hydraulic laws Moreover the phylogenetic telescoping of ontogenetic stages that takes place in human development is nowhere more convincingly mirrored than in this field of cardiac abnormalities and in the light of a clear visualization of the phases through which the embryonic heart travels and of the prototypes of these as seen in the fish reptilian and amphibian heart the most complex anomaly becomes reduced to very simple terms which he who runs may read It follows

that an elementary knowledge of embryology and comparative anatomy is essential for an intelligent grasp of this subject and of the possibilities involved in any combination of defects. For a brief survey of the main facts in the development of the heart, reference should be made to one of the standard monographs on congenital cardiac disease by Vierordt,[3] Keith,[4] Abbott,[5] Herxheimer,[6] Monckeberg,[6a] or Laubry and Pezzi.[7]

The causation of the arrest of growth that so frequently determines the existence of a cardiac anomaly should be sought chiefly in the environment of the developing embryo, in the form of disease in the fetal envelopes or maternal tissues, infective processes affecting the health of either parent at the time of conception, physical trauma or even psychic shock inflicted upon the mother in the first weeks or days of pregnancy, etc. All such pathological conditions set up or acting *in utero*, are liable to interfere with perfect uniformity of growth, minor deviations from which at this early period will result in slight asymmetries, while graver aberrations, such as those induced by mechanical torsion from amniotic adhesions, or other force, will end in all forms of monstrosities. That this is so, is abundantly demonstrated by the frequency of associated anomalies elsewhere in the body of an individual the subject of a cardiac defect; these occurred in 17 per cent of the 850 cases of congenital cardiac disease with autopsy analyzed by the writer[5] from the literature, and in 11 per cent of the 700 collected by Vierordt,[3] while Keith found an anomaly of the heart in 14 of 29 malformed fetuses examined. In 24 cases of complicated defects of the cardiac septa, Rokitansky[8] found eight with grave somatic malformations. It is proved also by the not unusual occurrence of cardiac anomalies in other members of the same generation (brother or sister), and by the history that frequently exists of infections, heart disease or syphilis in one or other parent, as also by the frequency of congenital lues in the subject of the defect. Heredity is apparently of relatively small importance as a factor in cardiac anomalies, though the association in some cases of conditions of known familial tendency, such as polydactylism, is undoubtedly significant and there are other facts pointing in this direction. But the early age at which most of the patients die prevents the transmission of qualities inherent in the germ plasm to another generation and impedes the accumulation of any significant statistical evidence of value for or against such conclusions.

The other etiological factor in the production of cardiac anomalies is *fetal disease*, both endocarditis and myocarditis. Less stress should be laid on *fetal endocarditis* which is, however, undoubtedly the cause in the relatively small group of congenital valvular lesions occurring in the later months of pregnancy after the cardiac septa have closed. Of much greater importance is *fetal myocarditis*, which has been shown by von Zalka[9] and others to underlie many of the cases of aortic or pulmonary atresia which are commonly associated with septal and other defects, and constitutes one of the gravest forms of morbus caeruleus.

Pathogenesis of Congenital Cyanosis: Raised oxygen unsaturation of the blood, which reveals itself clinically by the appearance of cyanosis may be the result of a variety of causes, acting singly or in combination Those actually producing it have been termed by Lundsgaard and van Slyke[10] influencing factors and are briefly: (1) Diminished oxygenation in the lungs due to pathological changes in the alveoli or capillary walls, or to lowered oxygen tension in the inspired air (C factor); (2) direct entrance of an anomalous current of venous blood into the arterial stream by way of a defect (*alpha* shunt); (3) increased deoxygenation at the periphery of the body (D factor), (4) an abnormally high hemoglobin content. Congenital cyanosis is produced by the second and third of these factors, namely a permanent venous arterial shunt and increased deoxygenation in the capillaries. In all cases, however, of long standing, secondary changes in the pulmonary capillary walls and compensatory polycythemia develop, so that all four "influencing factors" finally come to take part in the distressing clinical picture of the advanced stages of morbus caeruleus

In addition to the above which are directly causative or "determining," certain other so-called "modifying" factors (Lundsgaard) come into play which tend to alter the "threshold value" at which oxygen unsaturation in the capillaries becomes manifest to the eye as cyanosis. Such are: Thickness of the epidermis, variations in the skin pigment and altered color of the blood plasma, variations in the oxygen dissociation-curve, and in the number, width, length, and distribution of the skin capillaries, which differ widely in different normal individuals (Krogh,[12] Redisch and Rosler[11])

The amount of the venous arterial shunt may be calculated in terms of percentage of the total blood flow from formulas based on the follow-

ing values experimentally determined: (*a*) The oxygen content of the mixed arterial blood; (*b*) *the oxygen content of the arterial blood as it* leaves the lungs; and (*c*) the oxygen content of the mixed venous blood entering the right auricle. Of these values, the first two can be readily obtained. *The third, however, that* (*c*) *of the oxygen content of the* mixed venous blood entering the right auricle, presents great practical difficulties, since this figure cannot be directly determined in the human subject, *as in the case of experimental animals* (Zuntz[13]). Various attempts have been made to solve this problem by substituting other values for those of the venous oxygen content. Of these, probably the *most exact method is that followed by Weiss and Lowbeer*[14] *in what* must be considered to be the most complete calculation yet published; in it, they compute the venous oxygen content from the basal metabolic and circulation rates, *the latter figure obtained by the method of* Krogh and Lindhard.[15] W T. Dawson[16] proposed for the solution of this problem both the avoidance of the use of the venous-oxygen content and the computation of the circulation rate by substituting for the latter the values determined by Meakins, Dautrebande and Fetter for the rate of flow in a case of mitral stenosis, in which lesion circulatory conditions not unlike those in pulmonary stenosis might be assumed to exist His calculation, *as well as those of Weiss and Löwbeer and of Harold N* Segall on two cases of tetralogy of Fallot studied by the latter, are quoted in detail in a full discussion of this subject published by the writer.[17]

PATHOLOGY

The pathological changes in congenital cardiac abnormalities form a very *complex and diversified field, for they include both those condi* tions produced antenatally by arrest of development or fetal disease, and also those of later postnatal life, the result of compensatory changes *secondary* to the defect or of the infective processes that so commonly supervene. Only *the more important lesions will be briefly considered* here under the clinicopathological grouping outlined above, which greatly simplifies the presentation of this otherwise difficult subject

I. Lesions of the Acyanotic Group: (*a*) *Pericardial Defects:* These vary from complete absence of the parietal layer, as in the nonviable forms of ectopia cordis, to a more or less extensive defect of the left side of this structure, so that the pericardial cavity communicates freely with the left pleura either by a localized opening with serous margins or

(and this less rarely) by a deficiency so large that the heart and left lung come to lie in a common cavity The left phrenic nerve is displaced to the right in a degree increasing with that of the defect a point of value in the diagnosis of congenital origin The pathological significance of this condition lies in the abnormal juxtaposition of the serous surfaces of the heart and left lung which predisposes to inflammatory processes in both and in the existence of a *cor mobile* with consequent tendency to kinking of the great vessels and death

In *ectopia cordis* the heart is extruded from the thorax and comes to lie outside the body or in the abdominal cavity The only viable forms are those of pectoral heart with inferior sternal fissure and both layers of the pericardium present and abdominal heart in which the organ is protruded through a defect in the diaphragm into the abdomen Other forms of congenital displacements of the heart are the *dextro cardias,* due either to a transposition of the heart upon itself to an arrest of development at an early embryonic stage or to a combination of these two conditions such as usually occurs in the so-called *pure dextrocardia* in which mirror picture inversion of the heart is unaccompanied by situs inversus of the viscera on account of the grave associated anomalies these cases fall into the cyanotic group but the condition is mentioned here as it does not in itself produce cyanosis A condition that must be clearly differentiated from dextrocardia (due to factors intrinsic in the heart itself) is that of *dextroversio cordis* in which the heart is mechanically pushed or pulled over to the right side by pathological changes in other parts of the thorax as in congenital cystic disease of the left lung

(*b*) *Anomalies of the Heart as a Whole So called primary congenital hypertrophy* is a condition which may be present at birth in the absence of any valvular or renal lesion glycogenic infiltration or other apparent cause In several of the cases of this condition reported a curious anomaly origin of the left coronary from the pulmonary artery was associated and in one at least of these microscopic examination revealed areas of myo cardial degeneration and fibrosis which apparently had an etiological relation to the hypertrophy of congenital origin that undoubtedly coex isted In the remarkable case of this combination studied clinically by Bland White and Garland and reported by these authors [18] a definite symptomatology significant of myocardial changes in coronary disease existed The patient a male infant aged 3½ months appeared normal

until the tenth week, when paroxysmal anginalike attacks of acute distress, evidently of cardiac origin, set in, accompanied by signs of shock and sometimes followed by transient loss of consciousness (Stokes-Adams syndrome). The electrocardiogram showed normal axis deviation but well marked inversion of the T waves in all leads (coronary type). *Congenital rhabdomyoma* is another obscure condition of great interest in it the heart is the site of solitary or multiple tumor nodules consisting microscopically of a delicate reticulum supporting heterogeneous cells having an irregularly striated and vacuolated structure with peripherally placed nuclei resembling Purkinje fibers, while the brain and renal cortex show, in almost all the cases examined, disseminated areas of embryonic tissue. Multiple skin papillomas are frequently also associated. The subjects of this curious condition may live on into adult life but in that event they are usually afflicted with idiocy or epilepsy, the result of the cerebral sclerosis (Steinbiss[19]). *Congenital heart block,* a rare condition of great interest, is symptomatic of the deflection or interruption of the fibers of the bundle of His in their passage from auricle to ventricle by a cardiac septal defect or by a patch of myocardial degeneration or fibrosis. Only seven of the reported cases of congenital dissociation in the presence of a defective interventricular septum have, so far as is known to the writer, come to autopsy. Of these, four have been studied histologically in serial sections made through the atrioventricular node and the entire bundle of His region, and in all so investigated, direct interruption of the fibers between these two structures as a part of the developmental anomaly was clearly demonstrated. In the first of these cases, that observed by Wilson and Grant,[20] a cyanotic infant of 14 months with absence of the interventricular septum and pulmonary atresia which had presented during life a 2 to 1 heart block—alterations were found in the bundle fibers before these had left the auricular region. The second case (the first of Yater's[21] three cases of complete congenital heart block serially studied), a cyanotic male infant, 19 days old, presenting a small ventricular defect with incomplete hetorotaxy and complex somatic anomalies, "the complete anatomic separation of the a-v node from the bundle" made passage of the impulse to the ventricle impossible. In Yater's second case (third in the series), reported by him in conjunction with Lyon and McNabb,[21a] a male infant aged two months suffering from cyanotic dyspnoeic attacks, the heart presented a large

ventricular septal defect with complete absence of its membranous portion and the bundle of His was practically absent "as though punched out by the defect," while the a v node was practically normal in structure though somewhat displaced His third case (the fourth studied serially in the literature) reported by him with Leaman and Cornell,[21b] was a cyanotic male infant dying at 18 hours, which presented a cor trilobulare biventriculosum, practically complete absence of the auricular and of the membranous portion of the ventricular septa Here there was again no connection between the common auricle and the ventricles, the dissociation having been caused by "complete anatomic separation of the muscular conduction bridge"

An interesting case of *acquired* complete heart block, the direct result of sclerosis developing along the free border of a defective interventricular septum, has recently been serially studied by Yater, Barrier and McNabb[21c] The patient, a woman of 57, developed definite Adams Stokes attacks some two and a half years before death with delayed P-R intervals and an intermittent heart block, which progressed under observation to total atrio-ventricular dissociation, a condition that became permanent during the last six weeks of life Death followed prolonged attacks of syncope with convulsions Autopsy showed a huge persistent ostium primum with slightly defective ventricular septum, the mitral and tricuspid septal cusps becoming continuous across its free border The bundle of His, which ran along the latter, were markedly fibrotic, though the bundle branches below this area were intact and the a v node was of normal structure though somewhat dislocated from its position on the defect This was apparently the third case of persistent *ostium primum in which the* course of the conduction fibers was serially studied, the others being by Morison and Monckeberg[21c] The seventh case of congenital heart block with autopsy (not serially studied) in the literature is that by Dr Allan Roos, figured in Abbott's Atlas of Con genital Heart Disease, Plate XXV Figs 1a, b, c

(*c*) *Anomalous bands and chordae* occur and vary considerably both in pathological interest and in their etiology, according to their location in the different heart chambers In the *right auricle* a delicate fenestrated membrane or system of fine strands (network of Chiari), continuous with the eustachian or thebesian valves, may stretch across the cavity to be attached to the upper part of the auricular septum or adjacent parts, it

represents a persistence of the valvula venosa dextra, or sinistra, and is usually of little clinical import but may form a nidus for thrombotic processes leading to pulmonary embolism In the *left auricle* a curious anomaly may occur from the deflection to the left of the septum primum, and the entrance of one or more of the pulmonary veins into the small cavity so formed at the right upper part of the left auricle, forming what has been termed a double left auricle , the anomalous septum thus formed is usually a strong tendinous wall which carries a hole or opening (the foramen ovale) through which the blood passes from the right upper cavity into the lower part of the left auricle and thence to the mitral ostium, a certain amount of cardiac strain follows from the hampering of the blood stream so produced and several of the cases died at a relatively early age with signs of failing compensation (Church,[22] Borst,[23] William and Abrikosoff[24]) *Anomalous chordae* in the left ventricle occur, sometimes taking origin from the walls of this cavity and sometimes extending downward through the mitral orifice from an attachment in the left, or even in the right auricle (Goforth[25]) these may give rise to unusual adventitious sounds but are otherwise unimportant

(*d*) *Anomalies of the Semilunar Cusps* The aortic and pulmonary segments may be *increased* or *diminished* in number as a result either of excess formation or congenital arrest of development Supernumerary cusps are commonest at the pulmonary orifice but occur in both localities Four or even five segments (Peacock[26]) may exist and, of these two may be congenitally fused or incompletely divided, presenting a combination of both types of anomaly Reduction in number of the cusps is, however, more frequent than their increase and a *bicuspid aortic valve* is a fairly common abnormality, occurring either alone or in combination with certain 'left sided' lesions, especially coarctation and hypoplasia of the aorta, subaortic stenosis, patent ductus arteriosus, localized defect of the interventricular or aortic septum and persistent left superior cava The anomaly may consist of only two segments without trace of a third, and these are usually large and well formed and perfectly adapted to close the arterial orifice in the absence of postnatal inflammatory processes, which are extremely common and lead to thickening and deformities along their line of closure, resulting in incompetence and obstruction More commonly, however, one of the two cusps forming the valve presents on its arterial surface a low partly obliterated raphe

which represents the contiguous margins of the combined cusps and partly divides the sinus of Valsalva behind it The partial effacement of this raphe and the compensatory changes in the length and depth of the composite cusp to adapt it to its function of closure of the orifice which it screens, were points stressed by Osler[27] and others as differentiating the cases of congenital origin from those due to postnatal inflammatory fusion Louis Gross, however, showed on the basis of a careful serial study of 16 adult hearts[28] that such macroscopic criteria are of relatively little significance in determining the antenatal character of the lesion, and he concluded further, as did Bishop and Trubek,[29] that the micro scopic evidence of this, as adduced by Lewis and Grant[30] in their classic histological study of the architecture of the valve, should be revised in the light of a thorough serial study of the raphe in such instances as are undoubtedly congenital in origin These are the rare cases in infants in which a delicate raphe is present without any trace of inflammatory fusion, as also those occurring in young subjects with multiple associated anomalies. The grave clinical import of a bicuspid aortic valve lies in the nidus this presents for the invasion of infective processes (Osler,[27] Lewis and Grant[30]) and also the frequency of rupture of the aorta (Babes[31] and Deteindre) Bicuspid pulmonary valve is rarer than bicuspid aortic as an isolated lesion in combination however, with hypoplasia of the pulmonary artery in the developmental type of pulmonary stenosis (tetralogy of Fallot), it is a relatively common anomaly

(*e*) *Left side Valvular Lesions* *Subaortic stenosis* is a curious annular thickening of the endocardium of the left ventricle a few milli meters below the aortic valve and involving the base of the anterior mitral segment, which leads to a localized narrowing of the cavity and is in some cases at least, of congenital origin Its importance lies in the tendency which it presents to become the seat of an acute infective or chronic inflammatory process in early adult life, and the marked physical signs to which it gives rise in the absence of signs of serious obstruction of the aortic orifice *Stenosis of the aortic valve* itself, as a result of fetal endocarditis, is not very uncommon and interesting cases of aortic dwarf ism from this cause are recorded

Congenital mitral stenosis of inflammatory origin is probably much less frequent than was formerly supposed by the French writers when it

occurs, it is not uncommonly associated with a patent foramen ovale leading to the clinical picture described by Lutembacher[32] as mitral stenosis with interauricular insufficiency, though this combination may also occur postnatally, through the forcing open of a slitlike valvular patency by the raised pressure in the left auricle of an acquired mitral stenosis Donnally[33] collected 12 cases of congenital mitral stenosis in infants between one day and 3¼ years old but in only two of these was the lesion plainly inflammatory and due in the opinion of this author, to an infection in the parturient mother in six of the others there were structural changes in the valve of the nature of an arrest of development, and in four a septal defect with superimposed endocarditis In his own case the mitral orifice was minute and provided with a baggy undifferentiated valve, the left ventricle was aplasic and the aorta rudimentary, the ventricular septum entire and the foramen ovale and ductus arteriosus patent Such cases as well as aortic and mitral atresias the result usually of a fetal myocarditis just below the valve or of a primary arrest of development belong however in the cyanotic group and are only enumerated here for the sake of brevity

(*f*) *Coarctation of the Aorta* (*Adult Type*) In this curious anomaly there is a narrowing or stenosis amounting in some cases to complete obliteration of the lumen of the descending arch of the aorta at a point usually situated at or below the entrance of the ductus arteriosus which is commonly closed and is represented by a fibrous ligamentous cord The condition is apparently due to a faulty involution of the distal portion of the embryonic sixth left arch (ductus) at its junction with the primitive left fourth (which persists as the descending thoracic aorta) The changes resulting in the wall and lumen of the aortic isthmus become apparent as soon as the pulmonary circulation is established at birth when the obstruction thus produced in the aorta makes itself manifest by a rise of pressure in the arteries of the upper part of the body The result is the gradual establishment of a collateral circulation in the form of powerful anastomoses developing between the vessels given off from the aorta above and below the point of constriction (superior with inferior intercostals deep epigastrics with internal mammaries etc) by means of which life is maintained and the circulation carried on in some cases with little functional disturbance and with but slight evidence of the extraordinary deformity that exists Usually however, a varying degree

of strain is imposed which reveals itself by symptoms of vascular turgidity in the upper part of the body, and not infrequently leads to a fatal and dramatic termination in early middle life

Among 200 cases with autopsy (including one personal observation) collected by the writer[34] from the literature there were 47 of complete atresia of the descending arch 108 of extreme stenosis of the lumen which admitted a fine bristle to a crowquill and 45 of stenosis of moderate grade In 40 of these 200 cases death took place suddenly from rupture of the aorta and in 23 others from cerebral causes usually hemorrhage in ruptured congenital cerebral aneurysm in 14 other cases there was mycotic endarteritis of the aorta and in three of these rupture of a mycotic aneurysm at the seat of coarctation occurred Hypoplasia of the aorta and arterial system generally is commonly associated and may have a causal bearing on these fatalities and a bicuspid or otherwise anomalous aortic valve was present in 50 of the 200 cases In the writer s own case (reported with W F Hamilton[35]) a boy of 14 with complete obliteration of the aortic isthmus at the point of insertion of the ligamentum arteriosum a bicuspid aortic valve with dissecting aneurysm of the dilated ascending aorta and enormous dilatation and hypertrophy of the heart secondary to an aortic insufficiency of long standing and sub aortic stenosis death took place from cerebral hemorrhage eight hours after the onset of a hemiplegia

Other conditions of this group of some clinical importance are anomalies of the aortic arch especially *double aortic arch,* in which a vascular ring is formed by persistence of the fourth right arch the esophagus and trachea being enclosed between the two and *right aortic arch* in which the fourth right arch has persisted but the fourth left arch (normally the descending thoracic aorta) has disappeared and in which a vascular circle may again be formed if a patent ductus or ligamentum arteriosum persists and passes backward from its origin in the left pulmonary artery behind the trachea and esophagus to meet the anomalous right arch as it descends *Hypoplasia of the aorta* which is commonly associated with other anomalies occurs also alone and produces a characteristic habitus which is to be recognized as a distinct clinical entity

II Lesions of Arteriovenous Shunt (Localized Septal Defect)

(*a*) Defects of the *interauricular* septum may consist of a permanently

widely patent foramen ovale (not a valvular slit), or there may be an *opening above and behind the position of the foramen, in which case a* displacement to the right of the right pulmonary veins, so that these look into the right auricle, is commonly associated, or it may be situated below, with its upper margin formed by the lower free border of the interauricular septum (*persistent ostium primum*) and in this event there is always cleavage of the anterior segment of the mitral valve, producing a *congenital mitral insufficiency* or one or more of these defects may be combined with each other or with *multiple perforations* In either or all of these cases, if the auricular septal defects are of any considerable size, they are practically always accompanied by marked hypertrophy and dilatation of the right heart especially the right auricle, and dilatation with or without atheroma of the pulmonary artery

(*b*) Localized *defect of the interventricular septum* usually lies at the base just anterior to the pars membranacea septi and opens into the *sinus of the right ventricle behind the septal tricuspid segment and in* these uncomplicated cases is usually very small, admitting a knitting needle or a small probe, and has a rounded muscular lower border often with tendinous thickened edges Less frequently, the defect lies in the anterior part of the septum and in this case it opens into the conus of the right ventricle just below the pulmonary valve More rarely still, one or more small perforations exist in the lower part of the interventricular septum Usually very little change takes place in the size of either ventricle with *a localized defect in any of these locations* since this is not of much functional importance

(*c*) Localized *defect of the aortic septum* may occur either as a hole between the aorta and pulmonary artery a short distance above the valve or as an area of congenital thinning with subsequent aneurysmal dilatation in the right anterior aortic sinus of Valsalva, impinging upon or opening into the right ventricle at the level of the pulmonary cusps *This latter defect is not uncommonly associated with bulbar septal defect* in the anterior part of the interventricular septum just below the anterior aortic cusp Marked dilatation of the pulmonary artery, with hypertrophy and dilatation of the right ventricle, is always present when an actual communication exists through the defect or from rupture of a congenital aneurysm[76]

(*d*) In *patent ductus arteriosus* this vessel may persist as a short canal 0 5 to 1 5 cm long or it may be a mere hole between the contiguous right wall of the descending arch of the aorta and the left branch of the pulmonary artery, which vessel is practically always dilated as a result of the arterial venous shunt that is commonly taking place in the uncomplicated cases The lumen of the canal or opening may vary from the diameter of a fine probe or bristle to that of a lead pencil and is usually wider on its aortic side where it may appear at the bottom of a tent shaped depression The margins of the pulmonary orifice of a patent ductus are peculiarly liable to become the seat of an infective endarteritis which may involve the aortic orifice and may spread to the adjacent or opposite walls of either or both vessels with fulminating course[37]

III Lesions of the Cyanotic Group By far the most common abnormality in patients with congenital cyanosis reaching early adult life is the so called *tetralogy of Fallot,* in which a congenital stenosis of the conus of the right ventricle, with hypoplasia of the pulmonary trunk and frequently, a bicuspid pulmonary valve, is associated with a defect at the base of the interventricular septum and dextroposition of the aorta which rides over the defect or rises entirely from the right ventricle the marked hypertrophy of the right ventricle resulting from this combination supplying the fourth element in the ' tetralogy '

Less frequent and also of less serious import, is *pulmonary stenosis with closed ventricular septum,* due to inflammatory fusion of the pulmonary valves in later fetal life after the cardiac septa are completely formed The converse is the case in *pulmonary atresia* or complete obliteration of the outlet, which may occur with or without ventricular septal defect, in the latter case, a patent foramen ovale permits passage of blood to the left side, but life can only be sustained a few weeks, whereas patients with pulmonary atresia and ventricular septal defect may live some years, in either event, a patent ductus is almost always associated

In *transposition of the arterial trunks* the aorta arises from the right and the pulmonary artery from the left ventricle in more or less complete degrees of rotation The difficult circumstances into which the circulation is thrown is relieved by the remaining open of one or more of the fetal passages in the combined series of 94 cases analyzed on this point by Bokay[38] and the writer (*l c*,[5] p 729), the ductus was patent 63 times there was an auricular septal defect or a patent foramen ovale in

(d) In *patent ductus arteriosus* this vessel may persist as a short canal 0.5 to 1.5 cm long or it may be a mere hole between the contiguous right wall of the descending arch of the aorta and the left branch of the pulmonary artery which vessel is practically always dilated as a result of the arterial venous shunt that is commonly taking place in the uncomplicated cases The lumen of the canal or opening may vary from the diameter of a fine probe or bristle to that of a lead pencil and is usually wider on its aortic side where it may appear at the bottom of a tent shaped depression The margins of the pulmonary orifice of a patent ductus are peculiarly liable to become the seat of an infective endarteritis which may involve the aortic orifice and may spread to the adjacent or opposite walls of either or both vessels with fulminating course[37]

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79, and an interventricular septal defect in 31. As in pulmonary atresia, the presence of a ventricular septal defect is of major assistance in relieving the circulatory distress, and life was sustained in one case presenting this combination until the sixteenth year, with closed ventricular septum however (as shown by the above statistics the more frequent combination), transposition or reversed torsion of the great trunks is among the gravest forms of morbus caeruleus and death occurs in infancy

Absence of the interventricular septum (*cor biatriatum triloculare*) or of *both auricular and ventricular septa* (*cor biloculare*) leads to a permanent admixture of the venous and arterial streams in the systemic circulation with a resultant serious degree of congenital cyanosis In both these conditions transposition of the arterial trunks is not infrequently associated and possibly develops as an adaptation for the better conduct of the circulation, for subjects presenting this combination commonly *survive into adult life and present only a moderate degree of cyanosis* The same applies to the form of triloculate heart produced by *tricuspid atresia* with aplasic left ventricle and defect of the interventricular septum, thus, Hedinger's[39] patient, in whom these conditions coexisted lived to the age of 36 years and presented only an occasional blueness of the cheeks and lips In *persistent truncus arteriosus* the aortic septum is absent and a single large trunk provided with three or four or sometimes with five cusps (Simonds[40]) arises from right ventricle above a septal defect In *aortic and mitral atresia* circulation is maintained by a widely patent ductus through the pulmonary artery, which becomes continuous with the descending aorta and thus supplies the systemic circulation with mixed venous and arterial blood

(*d*) In *patent ductus arteriosus* this vessel may persist as a short canal 0.5 to 1.5 cm. long, or it may be a mere hole between the contiguous right wall of the descending arch of the aorta and the left branch of the pulmonary artery, which vessel is practically always dilated as a result of the arterial-venous shunt that is commonly taking place in the uncomplicated cases. The lumen of the canal or opening may vary from the diameter of a fine probe or bristle to that of a lead pencil and is usually wider on its aortic side, where it may appear at the bottom of a tent-shaped depression. The margins of the pulmonary orifice of a patent ductus are peculiarly liable to become the seat of an infective endarteritis which may involve the aortic orifice and may spread to the adjacent or opposite walls of either or both vessels with fulminating course.[37]

III. Lesions of the Cyanotic Group. By far the most common abnormality in patients with congenital cyanosis reaching early adult life is the so-called *tetralogy of Fallot*, in which a congenital stenosis of the conus of the right ventricle, with hypoplasia of the pulmonary trunk and frequently a bicuspid pulmonary valve, is associated with a defect at the base of the interventricular septum and dextroposition of the aorta, which rides over the defect or rises entirely from the right ventricle, the marked hypertrophy of the right ventricle resulting from this combination supplying the fourth element in the "tetralogy."

Less frequent and also of less serious import is *pulmonary stenosis with closed ventricular septum*, due to inflammatory fusion of the pulmonary valves in later fetal life after the cardiac septa are completely formed. The converse is the case in *pulmonary atresia* or complete obliteration of the outlet, which may occur with or without ventricular septal defect; in the latter case a patent foramen ovale permits passage of blood to the left side, but life can only be sustained a few weeks, whereas patients with pulmonary atresia and ventricular septal defect may live some years; in either event a patent ductus is almost always associated.

In *transposition of the arterial trunks* the aorta arises from the right and the pulmonary artery from the left ventricle in more or less complete degrees of rotation. The difficult circumstances into which the circulation is thrown is relieved by the remaining open of one or more of the fetal passages. In the combined series of 91 cases analyzed on this point by Bokay[38] and the writer (*l. c.*[7], p. 7-9), the ductus was patent 63 times, there was an auricular septal defect or a patent foramen ovale in

79 and an interventricular septal defect in 31. As in pulmonary atresia the presence of a ventricular septal defect is of major assistance in relieving the circulatory distress, and life was sustained in one case presenting this combination until the sixteenth year. With closed ventricular septum however (as shown by the above statistics the more frequent combination) transposition or reversed torsion of the great trunks is among the gravest forms of morbus caeruleus and death occurs in infancy.

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SYMPTOMS

Acyanotic and Cyanose tardive Groups. In both these conditions the cardiac abnormality may be entirely *latent*, producing no signs or symptoms until the sudden occurrence of some *crise d'amphithéater* such as rupture of the aorta or the appearance of a later or transient cyanosis gives information of the presence of the defect. More frequently in these cases the abnormality is associated with atypical physical signs which vary with the particular lesion. More or less characteristic however of both these Groups is the clinical picture of hypoplasia of the aorta which is so commonly associated with congenital left sided lesions and with localized uncomplicated septal defects, especially those of the

auricular or aortic septum and patent ductus Such patients are usually of tall slender build and delicate skin with a tendency to pallor of the surface and in pronounced cases signs of delayed puberty In coarctation of the aorta the subjects are commonly able bodied men (for this lesion predominates in the male sex) often of superior intellectual power who may present signs of increased blood supply to the upper part of the body as flushing of the face and epistaxis energetic pulsations in the neck and the characteristic vascular signs of dilated tortuous collaterals while the femoral pulse is diminished or absent In *right* or *double aortic arch* symptoms of dyspnea or dysphagia may occur from pressure on the esophagus or trachea from this source

Cyanotic Group The symptomatology of the cases of permanent venous arterial shunt and right sided valvular lesions on the other hand (Group III) is that of *congenital cyanosis* which is characteristic of all these cases and is present at birth in the most severe forms of morbus caeruleus but in the milder cases sets in insidiously after the threshold of oxygen unsaturation is passed as a bluish discoloration of the skin and mucous membranes which progress slowly to its culmination in the following distressing symptom complex (*a*) *Cyanosis* of the periphery of varying degree and becoming more marked in cold temperature and on increased muscular activity (*b*) *clubbing* of the finger tips toes and nose which gradually assume a bulbous flattened appearance from increase in the soft parts especially of the nail bed and thickened capillary walls the result of stasis and the accumulation of noxious products (*c*) *cyanosis retinae* in which tortuous thick walled capillaries and violet discoloration are visible in the eye grounds (*d*) *dyspnea* which is an early and prompt feature and frequently culminates in *dyspneic attacks,* seizures of extreme respiratory distress usually accompanied by a marked exacerbation of the cyanosis or by the transient appearance of this in conditions in which it was not previously manifest as in patent ductus arteriosus or in early stages of the milder forms of the cyanotic group (*e*) *polycythemia* which develops as a compensatory phenomenon but is of bad prognostic import indicating an advanced stage of the disease The red cells may number as high as 13 000 000 with a color index of 180 (*f*) curious epileptiform seizures or *syncopal attacks* may occur in late stages especially where the red cells are extraordinarily increased (*g*) *development is often stunted* and mentality may be below par though

some cyanotic patients with unusually *high intelligence* have been observed (Paul D White)

COMPLICATIONS

The most serious and frequent of these is the development of an *acute* or *subacute bacterial endocarditis* or *endarteritis* about the margins of or adjacent to the defect,[40] which supplies a nidus for the lodgment and accumulation of microorganisms from the circulating blood and also a *locus minoris resistentiae* for the inroads of the latter in the areas of sclerosis that almost invariably develop in the vicinity of these lesions, as a result of mechanical strain Such infections are the commonest cause of death in cases living on into adult life, especially bicuspid aortic valve and cardiovascular septal defects, as also the less severe forms of the cyanotic group as pulmonary stenosis In the graver cyanotic cases, such as persistent truncus transposition, etc, death usually occurs from the mechanical difficulties of the circulation (raised oxygen unsaturation, etc), at an early age, before such infections are liable to supervene *Chronic valvular disease* and *myocardial fibrosis,* secondary to healed or healing infective processes of milder grade, are very common and tend to complicate the picture in most cases of the acyanotic group reaching advanced life. A very important and interesting complication of cardiovascular septal defects is *paradoxical embolism,* in which a fragment, usually broken off from a thrombus in the iliac veins or right heart, passes through a patent foramen ovale or other anomalous opening into the greater circulation and lodges in the brain, spleen, kidney, etc *Pulmonary tuberculosis* is fairly common in lesions of the cyanotic group especially where, as in pulmonary stenosis, the blood supply to the lungs is reduced *Rupture of the ascending aorta,* with or without the formation of a *dissecting aneurysm,* is a relatively frequent termination in bicuspid aortic valve, hypoplasia or coarctation of the aorta In the latter condition it lies, in rare instances, in the descending arch *at the seat of coarctation,* and was due in three of these to a *mycotic aneurysm* Finally, *aneurysms of the smaller cerebral arteries,* apparently as a result of congenital weakening of the vascular wall at the point of bifurcation, occur in this same group of cases and cerebral death in young subjects may sometimes be traced to rupture of one of these

DIAGNOSIS

A double problem presents itself[41] First a congenital must be distinguished from an acquired lesion The following conditions are significant of the presence of a defect The youth of the patient a personal history of onset of signs or symptoms in infancy or early childhood and the absence of any record of infections as a cause for acquired valvular disease cyanosis when this exists whether as a transient or terminal phenomenon or as the hallmark of a permanent venous arterial shunt the presence of atypical physical signs

Secondly the differentiation of the particular lesion must be attempted This is a more difficult task and in the graver complicated anomalies of the cyanotic group an exact diagnosis may be impossible Even here however a knowledge of the possible developmental errors and subsequent anatomical changes that are liable to occur and of the approximate duration of life in the various combinations of these may narrow the field to the point of surmise and sometimes of certainty Thus in transposition of the great trunks and pulmonary atresia with closed ventricular septum or aortic atresia life is not sustained beyond infancy so that these combinations may practically be ruled out in subjects over a year old similarly persistent truncus may almost certainly be excluded after the tenth year and the only lesions likely to be present *in patients with congenital cyanosis who have attained adult life are* pulmonary stenosis (with or without ventricular septal defect) cor triloculare due to complete absence of the interventricular septum and tricuspid atresia with transposition of the great trunks (Hedinger[39]) Of these conditions by far the commonest is pulmonary stenosis with ventricular septal defect (tetralogy of Fallot) which is present in some 80 per cent of cyanotic subjects reaching adult life Characteristic of pulmonary stenosis with closed septum is a rough systolic murmur and thrill best heard at the second left interspace in the tetralogy these signs have the same point of maximum intensity but are usually less distinct or may even be absent and the murmur when present is commonly transmitted through the dextroposed aorta into the vessels of the neck while a systolic murmur generated at the defect may also be heard in the back below the left scapula in both types of pulmonary stenosis the second sound at the pulmonary area is usually weak and may be absent in older subjects clubbing becomes extreme and this and the

marked right preponderance in the electrocardiogram are important diagnostic features of pulmonary stenosis; but positive conclusions must be drawn with caution in these, as in all cases of congenital cyanosis, on account of the bizarre combinations that may exist.

The case is quite different in the "Acyanotic" lesions and those producing only transient or terminal cyanosis (Groups I and II), for physical signs are commonly present and are usually distinctive. This is especially true of the localized cardiovascular septal defects (Group II). Thus, in *defect in the interauricular septum* or *patent foramen ovale* the clinical picture is usually that of hypoplasia of the aorta in classic pronouncement and when, with the pallor and general habitus of this condition, there is a fugitive murmur of varying tempo and quality heard best over the third left interspace and sometimes accompanied by an obscure thrill, with signs of enlargement of the right chambers and dilatation of the pulmonary artery and its branches (shown by x-rays), a positive diagnosis is justified and is further clinched by the sudden appearance of cyanosis on the advent of pulmonary or other complications. In *defect of the interventricular septum* (maladie de Roger), the presence of a harsh prolonged holosystolic murmur, usually accompanied by a rough thrill, with maximum intensity at the third or fourth left interspace, in the absence of any disturbance of cardiac function and in an otherwise healthy individual who has presented these signs from childhood, is diagnostic; terminal cyanosis may occur but is less frequent than in auricular septal defects. Again, *defect of the aortic septum* produces dramatic and distinctive physical signs, a roaring continuous murmur heard loudest over the aortic area and upper part of the sternum and associated with a coarse continuous thrill apparently generated close to the chest wall and of so intense a vibration that it may actually stir the air a short distance from the surface of the thorax. Finally, in *patent ductus,* as was first pointed out by Gibson, a continuous rumbling "machinery" murmur localized over the first and second left interspaces is pathognomonic, and dullness and the "x-ray cap" in the same area produced in all advanced cases by the dilated pulmonary artery further confirm the diagnosis; in very young subjects the murmur is usually systolic and becomes continuous later; dyspneic attacks with transient cyanosis are a common feature.

Among the lesions without abnormal communication between the two circulations (Group I), *coarctation of the aorta* takes first place as presenting a diagnostic picture that is absolutely pathognomonic except in the few cases in which the lesion is so fully compensated that it remains latent throughout life. In most instances the long standing obstruction in the descending thoracic aorta reveals itself clearly by some erosion of the ribs visible by the x ray, and by the following vascular syndrome (1) Diminution of blood pressure in the lower extremities with retardation or obliteration of the femoral pulse in the presence of a contrasting hypertension in the upper extremities and (2) the combination with these of evidences of an extensive collateral circulation in the upper part of the body yielded by tortuous dilated peripheral vessels frequently transmitting a postsystolic murmur and fine thrill even in vessels so deep seated as to be otherwise imperceptible. *Subaortic stenosis* may be recognized by a persistent rough systolic murmur and coarse thrill over the aortic area without corresponding signs in the body or radial pulse of serious obstruction at the aortic orifice. *Bicuspid* or *supernumerary aortic segments* produce no signs until alterations from a superimposed endocarditis ensue but the existence of the congenital anomaly may sometimes be surmised in the presence of an acquired lesion from the coexistence of hypoplasia of the aorta and minor associated anomalies. Other left sided congenital valvular lesions present the same clinical picture as the acquired forms. *Anomalous chordae in the left ventricle* may give rise to peculiar adventitious sounds which can usually be distinguished from valvular murmurs by their high musical tone and atypical localization and by their rhythm which is commonly diastolic. *Congenital heart block* is present from infancy and is usually associated with a ventricular septal defect.

Laboratory Aids to Diagnosis *Electrocardiography* yields pathognomonic evidence of the nature of the defect in mirror picture dextrocardia in which all the curves of Lead I are inverted and Lead III replaces Lead II. In all other cardiac anomalies the significance of the electrocardiogram is only relative depending upon the anatomical position of the heart in the thorax and other obscure factors. Nevertheless in combination with other findings the direction and character of its curves do frequently yield supplementary evidence of much value. This is especially true where a left axis deviation coexists with signs of a

defect indicating as this does the presence of one of the rare left sided *congenital lesions or if cyanosis be present the possibility of a tricuspid* and pulmonary atresia (Taussig[4]) *with aplastic right ventricle An* extreme degree of right axis deviation again usually points especially in older subjects to the presence of a tetralogy of Fallot or transposition of the arterial trunks with preponderant hypertrophy of the right ventricle while a minor degree of right axis deviation with a high P wave and absence of physical signs of an acquired lesion is consistent with the presence of a large interauricular septal defect

Fluoroscopy on the other hand where the cardiac shadow is carefully studied by a competent observer both in the anterior posterior and in the right and left oblique and lateral diameters is of the greatest possible *help in arriving at a positive diagnosis for the method while it tells* nothing of the interior structure of the heart yields definite information from which conclusions may be drawn on the relative size of its various chambers the position and calibre of the great trunks at the base the contour of the aortic and pulmonary arcs and left cardiac border the presence or absence of pulsating hilar shadows the position of the aortic arch and the existence or otherwise of erosion of the ribs (significant of coarctation of the aorta) With the help of such findings the characteristic clinical picture *of large interauricular septal defect or widely patent foramen ovale with dilated and hypertrophied right chambers has been* established through the huge cardiac shadow occupying chiefly the left thorax with large pulmonary arc and narrow ascending aorta combined with moderate right axis deviation and physical signs absent or indefinite (Roesler[43] Nicolson[44])

So also in complete transposition of the great trunks an important diagnostic sign is supplied by the altered appearance of the aortico pulmonary shadow at the base of the heart which becomes narrowed in the A P position but *definitely broadened in the left oblique diameter where the two vessels become visible* lying more or less parallel to each other an appearance doubtless to be explained by the anticlockwise rotation of the great vessels upon each other so that the aorta comes to overlie more or less directly the transposed pulmonary artery This is pointed out by Dr H B Taussig[45] in a recent valuable communication who claims that the fluoroscopic evidence so adduced in the presence of persistent cyanosis is pathognomonic and *reports four cases of cyanotic*

infants in whom the diagnosis of complete transposition based on these findings was confirmed by autopsy. The contour of the cardiac silhouette was also altered in that both ventricles were enlarged but especially the right (the hypertrophy of this chamber being best seen in the left oblique diameter) and there was also some diminution in the shadow produced by the pulmonary conus. In a recent statistical study carried out at the Children's Hospital of Philadelphia by Rachel Ash[46] on 32 cases of cardiac defects with autopsy studied roentgenologically before death, there were eight of complete transposition and in several of these there was hypertrophy of the *left* ventricle and the electrocardiogram showed no right axis deviation.

A further very important practical aid in the differential diagnosis of cases of *arterial-venous* or *venous-arterial shunt* (Groups II and III) may be obtained through the new science of *angiocardiography*, in which the outlines of the superior cava, right chambers, and pulmonary circulation and the location of a septal defect, if one be present, are defined by the injection of a radiopaque substance immediately before roentgenography of the heart. In a recent communication, Castellanos, Pereiras and Garcia[47] have applied this method for the first time to congenital lesions in infants or children under six years with extremely interesting results. Their technic consists in the injection into the elbow or long saphenous vein of some 10 cc. in infants of a 35 per cent solution of *Per-Abrodil* or *Uroselectan B*. In children from four to six years a larger quantity, from 22 to 30 cc. of *Uroselectan B* is said to give the best results. Carried out as described by these authors in great detail, this procedure is said to be quite harmless. By a special contrivance of the x-ray tubes, both anteroposterior and lateral pictures may be taken simultaneously immediately following the injection.

In a later communication these authors describe still more brilliant results obtained by their use of a new automatic syringe (devised by A. V. Paussa[48]), which regulates by means of an electrical attachment the amount of radiopaque substance injected and its introduction at a known rate of flow. This device greatly facilitates the taking of perfect angiocardiograms by eliminating the personal factor, and also by reducing the time required for the operation, which is readily carried out in three or four minutes with perfect safety, simplicity and accuracy. The best results are said to be obtained in very young infants in whom a

smaller amount of injected material gives sharper contrasting shadows in the x ray picture Several cases of complete transposition of the great trunks confirmed later by autopsy have been recognized during life by these angiocardiographic studies, as also the first case of persistent truncus arteriosus so diagnosed *intra vitam*

PROGNOSIS

In the simpler and less serious lesions in which there is either no abnormal communication (Group I) or only that of a localized septal defect or patent ductus (Group II), the expectation of life is usually good in so far as the defect itself is concerned, although some cardiac strain is usually present and must be taken into consideration as a factor which is liable to come into play in early middle life, but the complications that are so frequent in these conditions, both infective endocarditis and chronic valvular disease, and, in the case of coarctation disease or rupture of the aorta, lead in the great majority of cases to an earlier fatal termination, often in the first years of adult life

In the subjects of congenital cyanosis, on the other hand (Group III), the course is progressively downward the duration of life depending on the nature of the defect, the amount of interference with the blood stream which it imposes and the associated anomalies which may be of the nature of adaptations for the better conduct of the blood In all cases, however, in which there is a permanently raised oxygen unsaturation of the blood from unalterable structural changes of congenital origin, a vicious circle is engendered which ends sooner or later in death from anoxemia of the tissues unless the course of events has been interrupted by exitus from an intercurrent complication

TREATMENT[49]

This is necessarily confined to *preventive* and *palliative* measures, for remedial treatment cannot be applied to structural changes in the heart, unless, indeed, by surgical intervention, and this is still in the experimental stage

Preventive treatment consists in (1) the *prenatal care of the mother*, especially in the early weeks of pregnancy, with the avoidance of strain, infections or traumas that could affect the environment of the developing embryo, and also in the actual prevention of conception between individuals who are themselves diseased, or the victims of alcoholism or

other poisons, or related to each other by ties of close consanguinity; (2) in the *protection* of congenital cardiac patients themselves *from overstrain* of the heart and from bacterial invasions at the seat of the defect by the *removal of foci of infection* and the *avoidance of colds* and *diseases involving the respiratory tract.* In the relatively large group of cases in which cyanosis is absent or terminal (Groups I and II), these measures are especially important, for the expectation of life is good so long as these patients keep within the limits of their cardiac reserve and so long as the vicinity of the defect does not become the seat of an infective endocarditis. In effect, these patients should be classed with those having healed rheumatic lesions, as "potential cardiacs," and awarded the same degree of protective care.

In the cases of the *cyanotic type* (morbus caeruleus, Group III), treatment is likewise preventive and palliative, but it should be realized that all that can be achieved here by the avoidance of complications and the maintenance of the best possible hygiene is the retardation of the inevitably downward course of the disease Symptomatic measures for the relief of the distressing symptoms that are liable to supervene may consist of *venesection* for the overloaded right heart; *diffusible stimulants, hot mustard bath,* etc, for the dyspneic attacks, and *sedatives* or *hypnotics* as indicated *Inhalation of oxygen* is of no direct benefit in a venous arterial shunt that has entered the systemic blood after it has left the lung, but it may give a little help in cases in which a pulmonary factor, as atelectasis, is also at work.

Surgical Intervention: The *surgical treatment* of *pulmonary stenosis* has been attempted by Carrel and Tuffier[50] and of *mitral stenosis* by Cutler and Levine[51] A new era in the treatment of congenital cardiac disease has been inaugurated in the establishment by Dr. Robert E Gross, Department of Pediatrics of the Harvard Medical School, of a relatively safe procedure for *ligation of a patent ductus arteriosus,* an operation indicated in suitable cases for the relief of cardiac strain and in the hope of preventing the onset of a subacute bacterial endocarditis In his special technic[52] devised on the basis of animal experimentation, the approach to the anterior mediastinum and the open ductus was made through the left pleural cavity anteroposteriorly above the compressed left lung The first successful case on record was operated by him in this way at the Children's Hospital at Boston on August 26,

1939 in a girl of 7½ years presenting the characteristic physical signs and *definite evidence of incipient cardiac embarrassment* The patient showed no signs of postoperative shock and recovery was complete on the seventh day when the dressings having been removed both thrill and murmur were found to have completely disappeared and the blood pressure had changed from 114 systolic and 38 diastolic to a daily average of 108 systolic and 80 diastolic This brilliant achievement was reported upon several months later by Gross and Hubbard [73] and this procedure *is being followed in many other institutions at the present time*

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CHAPTER III

RHEUMATIC HEART DISEASE

By Currier McEwen M D

Introduction As is obvious from the name rheumatic heart disease comprises those forms of cardiac damage which are due to rheumatic fever

Rheumatic fever in turn may be defined as a disease of undetermined etiology but apparently infectional chronic and recurring by nature but presenting acute phases and characterized by various manifestations of which the most typical are a toxic state carditis polyarthritis subcutaneous nodules and chorea

A brief historical sketch of what has been thought to constitute rheumatic fever in the past is helpful in understanding the modern concept of the disease As early as the sixteenth century the term rheumatism was used to designate vague joint and systemic symptoms and out of this group a type of migratory polyarthritis gradually emerged with which the name became linked For several centuries rheumatism was thought of as a disease affecting only the joints but in the late eighteenth and early nineteenth centuries it was learned through the observations of David Pitcairn (1788) Baillie (1797) Wells (1812) Hope (1839) Bouillaud (1837) and others that lesions of the cardiac valves and pericardium also occur in the disease

By the end of the nineteenth century subcutaneous nodules and chorea had been recognized as part of the disease picture and Cheadle (1889) had stressed the rheumatic nature of certain types of pleurisy and erythemas in children and had noted the relationship between rheumatic fever and tonsillitis In 1904 Aschoff contributed his important discovery of the myocardial lesions which bear his name and since then Klotz (191[illegible]) and Von Glahn and Pappenheimer (19[illegible]6) have described widely scattered changes throughout the vascular tree and

Klinge (1933) has reported characteristic lesions in mesenchymal tissues generally

Thus in the course of about 150 years the concept of rheumatic fever as a disease of the joints has broadened to that of a disease of protean manifestations involving tissues throughout the body However it must be borne in mind that during most of this period arthritis was considered to be the essential feature of the disease and heart involvement merely a complication Only in recent years has it been appreciated that no manifestation can be considered a complication but that all are integral parts of the disease state and only since that time has carditis assumed its proper place as the most important of the rheumatic manifestations

One of the reasons why carditis played so long a secondary role is that until fairly recently text book descriptions of rheumatic fever were based on observations of the disease as it occurs in adults in whom arthritis is apt to be a more dramatic and carditis a relatively less striking feature Various physicians like Cheadle (1889) and Barlow and Warner (1881) who saw the disease in children had thoroughly modern concepts of the place of carditis in rheumatic fever but they were brilliant exceptions

Two Subdivisions of Rheumatic Heart Disease *Before leaving this* introductory discussion it is necessary to consider a most important aspect namely the subdivision of rheumatic heart disease into the so called active and inactive phases *Active rheumatic heart disease* or *carditis* is the phase of inflammation of the heart and is a part of rheumatic fever *inactive rheumatic heart disease* is the stage of purely mechanical damage resulting from scarring caused by a previous attack of the active infection The situation is comparable to infections of the tendon sheaths of the hand During the active stage of such an infection there are systemic signs such as fever and leukocytosis and the hand is crippled because of the local inflammation Years later in the inactive stage after all evidences of infection have disappeared the hand still may be crippled because of scar tissue resulting from the earlier active inflammation

This distinction between carditis and inactive rheumatic heart disease is probably the most important single factor in a proper understanding of this subject and will recur repeatedly in the following pages

INCIDENCE

It is impossible at present to obtain more than an approximate idea of the incidence of rheumatic heart disease because rheumatic fever is not reportable save in Norway, Denmark and Iceland, and because in the case of many patients dying of heart disease the death certificates contain merely such diagnoses as cardiovascular disease, chronic cardiac valvular disease, myocarditis, endocarditis or pericarditis, without giving any information regarding the etiological type. However, a number of estimates have been made which probably give reasonably accurate figures. Thus, Swift (1931) estimated from a study of mortality figures that approximately 167,000 cases of rheumatic fever occurred in the United States in 1916 and in 1923. Since most attacks of rheumatic fever are associated with some degree of cardiac involvement, this figure probably gives some idea of the incidence of carditis but, of course, does not include cases of inactive rheumatic heart disease.

Such cases are included, however, in an estimate computed by Paul (1930) from the incidence of cardiac valvular disease in school children, drafted men, hospital patients and insured persons. According to this study of Paul's, there are about 840,000 people with rheumatic heart disease per 100,000,000 population. A study of hospital admissions provides another method of estimating the incidence of rheumatic fever and rheumatic heart disease. Swift (1931) reported that patients with rheumatic polyarthritis make up three to seven per cent of admissions to general hospitals in Europe and the United States. In an analysis of 5799 patients admitted to the adult and children's medical wards of the Third (New York University) Division of Bellevue Hospital during 1935, we found that approximately three per cent entered because of attacks of rheumatic fever in which carditis was a major component and 1.6 per cent because of inactive rheumatic heart disease. An additional 1.3 per cent had attacks of rheumatic fever in which evidence of carditis was not encountered—a total of 5.9 per cent due directly or indirectly to rheumatic fever. These figures probably represent fairly accurately hospital experience in New York City; they would be high, however, for the Southern States, for it has been shown that the incidence of rheumatic fever and rheumatic heart disease decreases as one goes from the Northern to the Southern States (Seegal and Seegal, 1927).

Still another means of estimating the importance of rheumatic heart disease is through etiologic classification of patients with cardiac disease. In such an analysis of 1051 cardiac patients, Wyckoff and Lingg (1926) found that over 25 per cent were of rheumatic origin, and this figure was very much higher for the younger age groups (see Fig. 1). Percentages such as these show very clearly the seriousness of rheumatic fever. However, when one considers that the victims of the disease are not the aged, but those who should have their most productive years still before them, the economic and social importance of rheumatic heart disease becomes even more striking.

It is possible to close this consideration of incidence on a somewhat brighter note, fortunately, because there is evidence that rheumatic

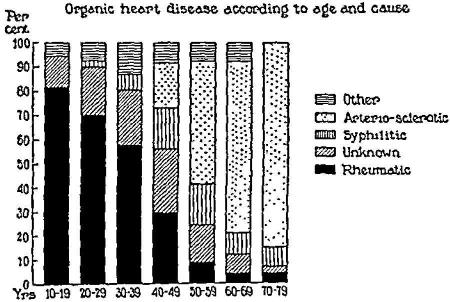

FIGURE 1. After Wyckoff and Lingg.

heart disease may be becoming less common. Thus Dublin and Lotka (1937) reported data which indicate that the annual death rate for valvular heart disease decreased from 61 per 100,000 in 1921 to 45 per 100,000 in 1930. On the other hand, it must be remembered, in evaluating these figures, that at least part of the apparent reduction may be due to more accurate diagnosis; for it is now recognized that many patients formerly thought to have organic valvular disease because of systolic murmurs in the presence of heart failure, actually had nonrheumatic heart diseases with relative mitral insufficiency.

ETIOLOGY

As has been said, inactive rheumatic heart disease results from a previous attack of rheumatic carditis and the etiology of the latter is that of rheumatic fever in general. Unfortunately, that is as far as one can go with confidence, for the cause of rheumatic fever has not yet been definitely determined and an etiological discussion under such circumstances obviously must be unsatisfactory. In spite of uncertainty regarding specific details, however, it is generally accepted that the disease is infectional in nature. Many different microorganisms have been thought to be the causative agent, including even the tubercle bacillus (Reitter and Lowenstein, 1930), but most of these are now of merely historical interest and only the streptococcus and filterable virus groups are given serious consideration today. The five more important recent theories are: (1) The view that the disease is caused by specific nonhemolytic streptococci (Small, 1927; Birkhaug, 1927; Cecil, Nicholls and Stainsby, 1929); (2) the theory that the underlying mechanism is tissue hypersensitivity to streptococci (Swift, Derick and Hitchcock, 1928); (3) the hemolytic streptococcal theory (Coburn, 1931, Coburn and Pauli, 1935); (4) Rinehart's (1935) hypothesis of infection superimposed on vitamin C deficiency; and (5) the filterable virus theory (Schlesinger, Signy, Amies and Barnard, 1935; Eagles, Evans, Fisher and Keith, 1937). At present the evidence linking hemolytic streptococcus infection with rheumatic fever is preponderant, but the explanation remains in doubt why some people develop the disease following such infections and others do not.

Regarding various predisposing factors in the epidemiology of rheumatic fever one can speak with more assurance. These are discussed in detail in Chapter IV, however, and will not be considered here.

STRUCTURAL CHANGES

The pathologic changes in rheumatic heart disease parallel the clinical stages of active and inactive disease. In active carditis the findings are those of inflammation, whereas in the inactive stage the lesions are those of scar tissue and adhesions. The changes in the various parts of the heart in active and inactive stages are briefly described below.

Myocarditis. The active lesion in the myocardium is characterized by the formation of Aschoff bodies. These collections of cells are found

most frequently in the basal portion of the ventricular wall, are usually perivascular, and located in the subendocardium. The Aschoff bodies consist chiefly of large basophilic often multinucleated cells with large vesicular nuclei. As the active inflammation subsides the nodules are changed into small foci of fibrous tissue. Although these characteristic lesions are focal in distribution the myocardium is diffusely weakened and dilatation occurs. Contrary to what is often thought the course of rheumatic heart disease clearly indicates that *the myocardial changes and not those in the valves are chiefly responsible for the appearance of heart failure.* As time passes the increased work imposed by the damaged valves and pericardial adhesions leads to myocardial hypertrophy. Combined with this there is often some dilatation even in the inactive stage if valvular inefficiency is pronounced.

Endocarditis and Valvulitis. The term endocarditis is generally used in a loose sense to mean inflammation not only of the endocardial lining of the valve but of the entire valve structure—a meaning which is much more accurately expressed by the term valvulitis. True endocarditis does occur however as part of valvulitis and as localized inflammation of the mural endocardium especially of the left auricle. The earliest change in rheumatic valvulitis appears to be localized edema with cellular infiltration and proliferation following rapidly. Usually at the line of apposition of the valves small areas of necrosis appear on top of which thrombi are laid down composed of fibrin and platelets. These can be seen grossly as small pinkish yellow vegetations on the valves and chordae tendineae.

As the process increases cellular proliferation and new capillary formation occur particularly at the base of the valve so that much of the valve becomes the seat of a chronic granulomatous inflammation. Healing takes place by organization and scar formation with the result that the valves become thickened, shortened and distorted. These changes prevent the proper closure of the valve and cause regurgitation. The same deformities plus fusion of the valve margins, and sometimes calcareous deposition interfere with the normal passage of blood through the orifice and cause stenosis.

The relative frequency of gross structural lesions in the various valves was found by Von Glahn (1927) to be as follows in a necropsy study of 109 cases: Mitral, 90.8 per cent; aortic, 57.7 per cent; tricuspid, 11.3

per cent, and pulmonic, 3 3 per cent However, microscopic inflamma tory *changes in the valve rings and deeper portions of the valve cusps* were found in a much greater percentage of cases by Gross and Fried berg (1936 *a* and *b*) and by Holsti (1928)

Pericarditis The pericardium loses its glistening appearance be *comes congested coated with fibrin and roughened Endothelial cells* swell and capillary proliferation occurs Probably in all cases some exudate is poured out which is serous in character If the amount is great enough to cause physical signs the patient is said to have pericarditis with effusion The character of the fluid is that of an exudate the num ber and proportion of the cells varying greatly in different cases and at different stages Early polymorphonuclear leukocytes predominate, but later there is an increase of clasmatocytes and lymphocytes

During either the fibrinous or the effusive stage resolution may take place This may result simply in a cicatricial thickening of the peri cardium without adhesion or in the process of healing adhesions may occur (chronic adhesive *pericarditis) between the visceral and parietal* layers of the pericardium and between the parietal layer of the peri *cardium and the pleura* mediastinal structures and diaphragm These adhesions may be merely slender bands but in the more severe cases they are dense and massive obliterating the pericardial sac and binding the heart to the lung diaphragm mediastinal structures or chest wall Adhesions of the latter type probably impose a serious burden on the heart, although pathologic studies have led some workers to doubt their importance as a cause of heart failure (Hosler and Bayless 1936)

Some degree of pericarditis was found by Von Glahn (1927) in 37 5 per cent of a group of adults and children coming to necropsy and by Findlay (1931) *in 51 3 per cent of a group composed solely of children* Gross and Fried (1936) reported at least microscopic pericardial lesions in 100 per cent of their cases in which death occurred during the stage of active carditis It is thus seen that in patients who die pericardial involvement is very common in many of these cases however, the lesion is of minor importance

Chronic Passive Congestion During the course of either active or inactive rheumatic heart disease the various pathologic changes which result from chronic passive congestion may appear—enlargement and

engorgement of the liver and other viscera, pulmonary congestion edema, ascites etc These are not part of rheumatic heart disease however, but are similar to changes occurring in congestive failure due to any other type of heart disease

SYMPTOMATOLOGY

From what has already been said it is clear that to a certain extent symptomatology must be considered separately for active carditis and for inactive rheumatic heart disease

Inactive Rheumatic Heart Disease While there are distinct physical signs of rheumatic heart disease in its inactive stage strictly speaking there are few symptoms for when complaints occur they usually are those not of heart disease but of heart failure Thus a patient with inactive rheumatic heart disease *may have no symptoms* at all *or may suffer various degrees of cardiac insufficiency* up to frank congestive heart failure even at rest That signs of failure should appear is not surprising in view of the mechanical inefficiency resulting from the defective valves pericardial adhesions and myocardial scarring Indeed *one of the striking features of inactive rheumatic heart disease is the* paucity of symptoms experienced by many patients with extensive valvular damage so long as the myocardial efficiency remains good Evidences of failure promptly appear however when new attacks of rheumatic activity bring recurrences of myocarditis or when coronary insufficiency leads *to* myocardial fibrosis as the patients grow older

Active Rheumatic Heart Disease (Carditis) Since this is merely one manifestation of active rheumatic fever other evidences of that disease are usually present such as fever polyarthritis chorea subcutaneous nodules erythema marginatum pleuritis and others When these are definite *diagnosis is* easily made and even without other rheumatic manifestations there *is little difficulty in recognizing carditis when the involve*ment of the heart is acute and severe for one s attention is immediately drawn to the heart by such signs as dyspnea orthopnea and precordial pain It is in the more subacute forms without distinct rheumatic manifestations that difficulty is encountered for such patients may complain merely of *vague* muscle or joint aches fatigability loss of appetite and other indefinite symptoms *It is important therefore to bear in mind* the varied ways in which rheumatic fever may manifest itself and to watch with great care any patient presenting these possibly rheumatic symptoms

This is particularly true in the case of children in whom cardiac damage is apt to develop insidiously These other manifestations of rheumatic fever are not considered in detail here since they are covered fully in Chapter V

The term *carditis* is particularly useful in describing active rheumatic heart disease because the heart usually is attacked as a whole in contrast *to the known bacterial infections of the heart which attack predominantly* one structure—endocardium or pericardium Once having made the diagnosis of carditis however one should attempt to learn by careful observation to what degree the various parts of the heart are suffering

Myocarditis Probably because of the striking murmurs which persist into the inactive stage of rheumatic heart disease most of the earlier observers emphasized involvement of the endocardium Today however it is fully realized that the most important lesions so far as concerns the ability of the heart to perform its required work are those in the myocardium That this is so is apparent when one considers the many patients who have marked failure during an attack of carditis but who have excellent cardiac reserve when the active disease has subsided in spite of the persistence of severe valvular defects Indeed one may say almost categorically that *young rheumatic patients do not go into frank heart failure in the absence of myocardial inflammation* In older patients this is less true especially in the age groups where degenerative diseases of the myocardium become important but in a patient under 40 with cardiac disease of the rheumatic type the appearance of frank heart failure is presumptive evidence of the reappearance of active infection Other signs and symptoms which point to myocarditis are enlargement of the heart while the patient is under observation precordial pain and tenderness tachycardia out of proportion to fever and various electrocardiographic abnormalities Also since myocarditis probably always accompanies rheumatic valvulitis and pericarditis to at least some degree the presence of any signs pointing to active involvement of them is presumptive evidence of myocarditis as well

Valvulitis It was mentioned in the discussion of pathology that so far as rheumatic heart disease is concerned the term endocarditis is now confined principally to inflammation of the mural endocardium and the word valvulitis is used to designate the valvular inflammation That this is more accurate is shown by studies which have demonstrated that the

essential and earlier changes in the valves occur deep in their substance and that the small surface vegetations form later at the site of breaks in the lining endocardium Clinically the commonest valvular lesion is mitral insufficiency Next in frequency and most characteristic of rheumatic heart disease is mitral stenosis The lesion third in frequency is aortic insufficiency while aortic stenosis is fourth Pathologically lesions of the tricuspid valve are relatively common and those of the pulmonic valve occur in 3 3 per cent (Von Glahn 1927) but clinically they are difficult to diagnose The signs by which these valvular defects may be recognized are considered in Chapter XIX These lesions usually persist once they have given rise to the murmurs which distinguish them but occasionally they disappear particularly in the case of aortic insufficiency The probable explanation of these transient murmurs is inflammatory edema of the aortic leaflets with subsidence of the infection before the development of sufficient proliferative changes to cause permanent valvular deformity Transient apical diastolic murmurs also sometimes occur and have been thought (Bland White and Jones 1935) to be due to dilatation of the left auricle and ventricle resulting in relative stenosis of the less distensible mitral ring It is probable that true stenotic deformities do not occur until after weeks or months of valvulitis because it is unlikely that sufficient thickening and deformity to cause obstruction to blood flow through the valve orifices can occur rapidly

The appearance of a systolic murmur during the course of rheumatic fever is of course merely presumptive evidence of valvulitis because *such murmurs are so common in other acute infectional diseases which do not cause organic heart disease* The appearance of new diastolic murmurs while the patient is under observation on the other hand may be considered conclusive evidence of valvulitis

Pericarditis Pericarditis of clinical degree is rare in adults as compared with children and usually is indicative of severe cardiac involvement Frequently it is of serious prognostic significance because of the danger of cardiac tamponade during the acute phase and because of the possibility of extensive pericardial adhesions later On the other hand patients with definite *pericarditis sometimes recover without any signs* of permanent cardiac damage Presumptive evidence of pericarditis is provided by rapid increase in the size of the heart with pyriform shadow on X rays and by *certain electrocardiographic changes* (see page 6[illegible])

The diagnosis is established by the appearance of the typical double shuffle friction rub over the precordium A large pericardial effusion like extensive pleural effusions can give rise to pulmonary physical signs highly suggestive of consolidation This is of considerable practical *importance because it may lead to an erroneous diagnosis* of rheumatic pneumonitis or lobar pneumonia

Signs and Symptoms of Carditis Because of the great importance in the management of a patient with rheumatic heart disease of recognizing the presence or reappearance of carditis signs and symptoms of this manifestation are reiterated Among the conclusive signs are (*a*) The development of heart failure during an attack of rheumatic fever (*b*) the appearance of a pericardial friction rub (*c*) the development of new diastolic murmurs and (*d*) significant increase in the size of the heart—all if they occur during an attack of rheumatic fever Among the presumptive signs are (*a*) Precordial pain and tenderness (*b*) tachycardia out of proportion to fever (*c*) gallop (*d*) the presence of subcutaneous nodules (*e*) prolongation of the atrioventricular conduction time and various other electrocardiographic abnormalities (*f*) the *development of* auricular fibrillation or congestive heart failure in any patient with physical signs of rheumatic valvular defects particularly in *patients under 40 (g) fever increased erythrocyte sedimentation rate or* leukocytosis in any rheumatic subject in whom these signs cannot be otherwise accounted for and (*h*) indeed the appearance of any manifestation of active rheumatic fever especially in a young patient or in the presence of physical signs of rheumatic valvular defects Quite obviously some of these presumptive signs should make the observer merely suspicious of carditis whereas others such as the development in a *patient* with rheumatic polyarthritis of precordial pain or prolonged conduction time are almost conclusive Often one can arrive at a decision *as to whether or not active carditis is present only after careful* observation of a patient for many days

Symptoms The symptoms of *congestive heart failure* need not be discussed here since they are similar to those accompanying any type of heart disease (see Chapter XXXIV) Pulmonary congestion however is apt to be more striking in failure due to other types because of the back pressure caused by mitral stenosis

Various *arrhythmias* are relatively common in the inactive as well as the active stage, particularly auricular fibrillation and premature contractions. In patients under 40 the development of auricular fibrillation suggests a return of carditis, but as the patient advances in age this probability diminishes.

Cardiac pain is a much less common symptom in inactive than in active rheumatic heart disease, but when it does occur it is usually much more severe. Pain accompanying carditis is customarily a persistent dull ache localized in the precordium That of inactive rheumatic heart disease is apt to be truly anginal in type, often excruciating, and radiating to the left shoulder and arm It is associated with elevation of the blood pressure and is relieved by amyl nitrite This type of pain in rheumatic heart disease occurs in patients with aortic insufficiency and aortic stenosis and probably is caused by myocardial anoxemia resulting from inadequate coronary filling.

Physical Signs: Physical signs of inactive rheumatic heart disease are those of the various valvular defects caused by rheumatic valvulitis and of cardiac enlargement The character of the latter is described in the discussion of x ray findings in Chapter XXIX. The signs which distinguish the various valvular defects are detailed in Chapter XIX

COURSE OF DISEASE

From the foregoing it is clear that active rheumatic heart disease is vastly more important than the inactive stage of the disease, for the latter occurs only as a result of the former and is made progressively worse by repeated attacks. Thus, the course and prognosis in any given case depend mainly upon three factors The severity of the attacks of carditis; how long they last, and how often they are repeated. On the basis of these factors four clinical types of course may be described.

(1) Acute Fulminating Type: In this type the disease runs a rapid course with high temperature and leukocytosis, marked signs of heart failure, and death within a few days to several months This type is rare, especially in adults. In a recent analysis of 70 children under 12 years old in Bellevue Hospital with their first attacks of rheumatic heart disease, three or 4.3 per cent, were of this kind, and died during the attack. Among 67 adults over 25 years old, there were no such cases in first attacks of rheumatic carditis (DeLiee, Dodge & McEwen, 1939).

Case Report I Patient, E. G., a seven year old female child was admitted to the hospital on April 17, 1939 Her family history and her own previous history were noncontributory The present illness had begun six weeks earlier when she developed an attack of tonsillitis with which she was confined to bed for two weeks She then returned to school for a few days but on March 23 developed pain in both knees and again was forced to bed Subsequently these joints then the wrists and ankles, became red swollen and very painful The temperature varied between 37 8° and 40° C (100° and 104° F) and there was an evanescent rash For one week prior to admission she complained of shortness of breath and on April 16 developed precordial pain which induced her parents to bring her to the hospital

On admission she was acutely ill with marked pallor and moderate dyspnea The inflammation of the throat had entirely subsided Lungs and abdomen appeared normal The heart showed enlargement, sounds were faint there was a gallop at the apex and also a systolic murmur transmitted to the axilla There was a questionable diastolic murmur at the apex but none at the base No thrills nor pericardial friction sounds were heard Blood pressure was 98/48 The extremities showed no evidence of edema Laboratory data revealed the following Erythrocyte sedimentation rate (Cutler method) was between 30 and 35 mm in one hour at each of several determinations there was a moderate secondary anemia and 10 250 leukocytes of which 71 per cent were polymorphonuclear cells the urine was normal two blood cultures were negative Frequent electrocardiograms showed right axis deviation and P R intervals between 0 26 and 0 32 sec

Several days after admission subcutaneous nodules began to appear and became numerous On April 26 she appeared definitely worse and extensive erythema marginatum was noted On April 28 some dullness and diminished breath sounds were noted at the right base and the liver edge was felt for the first time Because of these signs of beginning congestive failure digitalis therapy was begun In an attempt to arrest the progressive downward course, three small transfusions were given within the next week but apparently did no more than improve the anemia temporarily On May 14 a friction rub was noted at the left base suggesting pleuritis and for the first time a water hammer pulse with a blood pressure of 108/0 was observed and a diastolic murmur was heard at the base of the heart During the next few days evidence of congestive failure became more marked and persistent vomiting occurred which was apparently due to visceral congestion and not to digitalis toxicity In spite of diuretics and oxygen therapy ascites appeared and dyspnea became extreme On June 2 the patient died suddenly The temperature had ranged between 39° and 39 5° C. (102° and 103° F) during the

matic activity He was readmitted to the hospital on February 3 1931 but was signed out by his parents against advice ten days later

He was followed subsequently at the cardiac clinic and in the hospital and was admitted eight additional times in all of which he was signed out by his parents against advice after being in the hospital six weeks or less During all of his admissions and most of the period of attendance at the clinic there were precordial pain and mild dyspnea on exertion and on two or three occasions mild swelling and pain in several joints On June 5 1931 a basal diastolic murmur was first heard and subsequently the confirmatory signs of aortic insufficiency appeared In April 1932 a cough with blood streaked sputum was present for two weeks but there were no other evidences of congestive failure

On May 11 1934 he entered the hospital with acute polyarthritis carditis and epistaxis which occurred following acute pharyngitis contracted during a wave of upper respiratory infections in his family During this attack pericarditis was present with a friction rub followed by massive effusion Marked dyspnea developed which was much relieved by pericardial paracentesis During this attack evidence of congestive failure became more marked and digitalis therapy was begun During the remaining 16 months of his life he was in and out of the hospital three times during each of which he was extremely ill and showed increasing evidences of heart failure in spite of digitalis and diuretics

His last admission was on August 22 1935 at which time he showed marked ascites and edema pulse rate of 180 moderate fever substernal discomfort and severe dyspnea orthopnea and cyanosis In spite of abdominal paracentesis and treatment in an oxygen tent his symptoms became progressively worse and he died on August 24 with a final cardiac diagnosis of A Rheumatic fever inactive and active B enlarged heart mitral stenosis mitral and aortic insufficiency adherent pericardium carditis C sinus tachycardia prolonged A V conduction time congestive failure D IV E

Comment This case illustrates the chronic active type of rheumatic heart disease Apparently this patient s first attack of rheumatic fever began shortly before he was first seen in 1930 and continued with persistent low grade carditis interrupted by exacerbations of more pronounced rheumatic activity until death five years later Because of the patient s persistent refusal to remain in the hospital adequate rest was never obtained Whether the course would have been so progressively downward if adequate treatment had been possible it is not possible to say

(4) Persistently Inactive Type This clinical type unfortunately rare is ushered in with an attack of carditis which after a few months becomes inactive Healing takes place with or without cardiac enlargement or valvular disease The infection does not return and such patients not infrequently live their natural expectancy of life

Case Report IV Patient P G age 19 an Irish male was admitted to the hospital on February 10 1930 with rheumatic fever Family history revealed rheumatic fever in a cousin but none in three siblings or in his parents There was no past history of rheumatic fever in the patient and there had been no unusual morbidity from the usual childhood diseases

On January 11 a head cold had begun which lasted about ten days and on January 29 after he had been completely well for a week he first noticed pain tenderness and swelling of the knee and toes of the left leg Within several days the arthritis spread to involve both knees and ankles and he was confined to bed At the time of admission on February 10 both knees and ankles were extremely painful tender swollen red and warm to the touch Temperature was 39 3° C (102 6° F) pulse rate 106 leukocyte count 20 500 Examination of the heart revealed a gallop and a systolic blowing murmur at the apex

Aminopyrine was begun 0 3 Gm five times daily on the second day of admission with prompt decrease in joint involvement so that only very slight pain and tenderness remained At the same time temperature and pulse fell to essentially normal and the white blood cells to 14 000 In spite of this general improvement precordial pain and tenderness were first noted on February 13 and on that day the electrocardiogram showed the P R interval to be 0 30 sec It subsequently rose to 0 40 sec. and then fell again to 0 26 sec where it remained up to the time of discharge On March 26 subcutaneous rheumatic nodules appeared over the elbows knees and ankles For a time new ones developed but by the middle of May all had subsided During April a diastolic blowing murmur was heard at the apex which was inconstant and disappeared after four weeks The gallop likewise disappeared during May and by May 26 he appeared to be in good general condition when his tonsils and adenoids were removed

Weight on admission was 64 kilograms but it rose to 71 at the time of discharge from the hospital in June At that time there remained as evidence of the rheumatic episode merely a soft systolic murmur at the apex and the prolonged P R interval of 0 26 sec. At a follow up examination in August 1930 the P R interval was still prolonged but when seen a year later it had returned to a normal of 0 16 sec Although there was a soft systolic murmur at the apex there was no evidence of enlargement of any of the chambers of the heart on x ray examination He felt

perfectly well at that time and was working as a laborer. The patient has subsequently been followed at intervals for nine years during all of which time he has continued to be well and has shown no evidence of recurrent rheumatic fever or cardiac changes.

Comment: This case is cited as an example of the persistently inactive type of rheumatic heart disease. The patient presents an unusual feature in the persistent prolongation of the auriculoventricular conduction time. The case also illustrates the fact that subcutaneous nodules do not always indicate serious cardiac damage.

ELECTROCARDIOGRAPHIC FINDINGS

In Active Carditis: The electrocardiographic changes encountered in active rheumatic carditis may be discussed conveniently under four headings: Prolongation of the auriculoventricular conduction time, abnormalities of rhythm, abnormalities of Q-R-S and T waves, and changes associated with pericarditis.

(1) *Prolongation of the Auriculoventricular Conduction Time:* Isolated cases of heart block were reported in the early years of the present century, but the real importance of this sign in rheumatic carditis was appreciated, of course, only after the advent of electrocardiography (Parkinson, Gosse and Gunson, 1919-20; Cohn and Swift, 1924). The reported incidence of prolonged conduction time varies with the criteria employed and the frequency with which tracings are taken. Cohn and Swift (1924), who took daily electrocardiograms and who considered as a significant change any definite increase even though it did not exceed 0.20 second, obtained an incidence of 84 per cent.

Master and Jaffe (1932) likewise took daily tracings and found that in 12.8 per cent of 63 patients the P-R interval reached 0.20 second and in 57.6 per cent it exceeded 0.20 second. Other investigators, however, who took electrocardiograms at less frequent intervals reported a much lower incidence. Thus it is apparent that, while prolonged conduction time is an important sign of carditis, normal findings have little weight in excluding the presence of carditis unless the tracings are taken at frequent intervals.

There is some question, too, as to what should be considered a significant increase in the P-R interval. If one has only a single electrocardiogram on which to base an opinion, it is probable that only figures of more than 0.16 second should be considered significant in a child under 14, or

of more than 0.20 second in an adult. On the other hand, since the normal P-R interval for a given individual shows little variation from day to day at a constant heart rate, definite increase in serial tracing may be just as significant as a single electrocardiogram with figures above the upper limit of normal. Here again, however, judgment must be used in interpretation, because the P-R interval increases normally as the heart rate slows (Ashman and Hull, 1937). Thus a very slight increase in P-R interval is important if the heart rate increases or remains constant, but with a drop in rate, an increase in conduction time must be more marked to be significant.

Most commonly the prolongation of auriculoventricular conduction time can be demonstrated only with the aid of the electrocardiogram, but occasionally the impairment is so great that some beats are dropped. This occurred in 22 per cent of the patients studied by Cohn and Swift (1924) and in 4.8 per cent of those studied by Master and Jaffe (1932). Not infrequently varying block appears and dropped beats occur irregularly. Rarely there is complete A-V block, and the ventricle responds at a slow rate to an idioventricular center. As a rule the impairment is transient, lasting from less than a day to several weeks, although it may recur two or more times during the course of a single attack of carditis. Occasionally the prolonged conduction persists for months, even after all other evidences of rheumatic activity have subsided (see Case Report IV, page 58), and rarely it is permanent.

It has been shown repeatedly that the degree of impairment has no relationship to the height of fever nor to the severity of carditis. The explanation of the phenomenon usually advanced is that of a structural defect involving the conducting tissue in the auricle. When impairment is transient the pathologic change is thought to consist merely of edema; when more persistent, Aschoff bodies in the conducting bundle are hypothesized; and when permanent, scar tissue is thought to have been laid down. The idea of intercellular edema was supported for a time by the report (Levy and Turner, 1927) that block disappeared following the administration of salicylates. However, subsequent studies (Wyckoff, DeGraff and Parent, 1930; Master, 1927; Master and Romanoff, 1932) did not bear this out. Recently Bruenn (1937) has reported that the impairment of conduction was abolished transiently in 19 of 22 cases by the intravenous injection of atropine, indicating that the prolonged

auriculoventricular conduction time is due, at least in part, to an increase in vagal tone. Bruenn suggests that the focus of vagal irritation lies in the medulla.

While prolonged auriculoventricular conduction occurs most frequently *in active rheumatic carditis, the phenomenon is*, of course, not limited to that disease It occurs next in frequency in arteriosclerotic and in hypertensive heart disease (Levy and Turner, 1929) and also in bacterial endocarditis (Rothschild, Sacks and Libman, 1927, Levy and Turner, 1929), to mention only a few Since digitalis increases the P R interval, the interpretation of tracings from patients receiving that drug must be made with care

(2) *Abnormalities of Rhythm* The various arrhythmias which can be detected at physical examination are more accurately recognized by electrocardiographic study While all types of irregularity may occur, the commonest are auricular and ventricular premature contractions and auricular fibrillation Various types of premature contractions were recorded in 62 per cent of 37 patients by Cohn and Swift (1924) and in about 15 per cent of 63 patients by Master and Jaffe (1932). Auricular fibrillation was found in 14 per cent and 3 2 per cent by the same authors, respectively Less frequently encountered irregularities are auricular flutter, nodal rhythm and paroxysmal tachycardia

Tachycardia is an almost universal finding at some stage of carditis Much less well known, but fairly common, is sinus bradycardia, which, however, usually changes to tachycardia after a few days or weeks A number of authors have called attention to the fact that the sinus arrhythmia so often present normally, especially in children, tends to be lost in the presence of carditis Indeed, the return of sinus arrhythmia in a patient with active rheumatic heart disease is usually a sign of improvement

In regard to auricular fibrillation it should be stated that when it occurs in early attacks of carditis it usually is paroxysmal and transient However, when it occurs later in the course of disease, after severe structural defects have occurred in the heart, it usually persists

(3) *Abnormalities of Q R-S and T Waves*· Various alterations in the ventricular complexes may be noted during the course of rheumatic carditis, but none is necessarily indicative of that disease Indeed, such changes as occur are frequently within the limits of normal and can be

the abnormalities of Q R-S and T noted in these patients are due to arteriosclerosis and not to the old rheumatic lesions.

DIAGNOSIS

The diagnosis of rheumatic heart disease resolves itself into answering a number of quite different questions which may arise in individual cases First, given a patient with rheumatic fever, one must decide whether or not the heart is involved. This usually is a more or less academic question, especially in children, because some degree of carditis is so common in rheumatic fever that the patient must be assumed to have it until it is

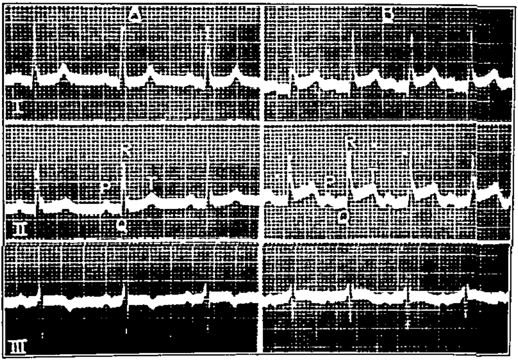

FIGURE 2 Electrocardiograms taken before (A) and after (B) the onset of pericarditis In B note the elevation of the R T segment in Leads I and II without reciprocal changes in Lead III There is also slight prolongation of the P R interval in both A and B

proven that he does not The various signs and symptoms of carditis enumerated on page 52 usually enable one to reach a decision.

A second type of problem, and a much more difficult one, is that set by the child who has vague symptoms which may or may not be rheumatic, such as listlessness, epistaxis, failure to gain weight, and secondary anemia; perhaps also with fleeting pain in an extremity, slight tachycardia and a blowing systolic murmur. If some rheumatic manifestation becomes

definite, the problem resolves itself into that discussed in the paragraph above; but if not, one can merely observe the child carefully—again with particular emphasis on the various conclusive and presumptive signs of carditis.

The patient with physical signs of heart disease of the rheumatic type who is seen because of malaise and fever presents a third type of problem; namely, whether the evidences of infection are due to a coincidental illness such as influenza, or whether a new attack of rheumatic activity has started. Again one can merely observe and wait for an indication one way or the other. While waiting, however, the patient should be assumed to have carditis and be kept in bed.

A final question and a frequent one is presented by the patient with obviously inactive cardiac valvular disease in whom it must be decided whether the original etiological factor was rheumatic fever or some other cause. As a rule this is not difficult, because the combination of a past history of rheumatic fever plus physical signs of mitral stenosis is usually present in rheumatic cases and leaves little doubt. Even in the absence of a rheumatic history the finding of a characteristic apical diastolic murmur usually means rheumatic heart disease, although there are some exceptions (see below).

DIFFERENTIAL DIAGNOSIS

Only a few of the diseases which may be confused with carditis and with inactive rheumatic heart disease are considered here.

Carditis: *This can be simulated by a number of diseases, among which are bacterial endocarditis, hyperthyroidism, sickle cell anemia, leukemia, and undulant fever.*

Bacterial endocarditis is particularly confusing because it is so often implanted upon inactive rheumatic heart disease. Usually, however, the appearance of embolic phenomena and a positive blood culture soon make the nature of the infection clear.

Hyperthyroidism with its accompanying tachycardia, forceful heart action, and low-grade fever sometimes leads to an erroneous diagnosis of rheumatic carditis. This is especially true in those cases in which a "slurring" of the heart sounds at the apex gives rise to what simulates a diastolic rumbling murmur. This sound disappears following adequate iodine therapy, however, as do the other symptoms.

Sickle cell anemia and leukemia both may be mistaken for rheumatic fever with carditis because of the muscle pains anemia, murmurs and cardiac enlargement which may occur Suitable examination of the blood, of course points to the correct diagnosis

Undulant fever and various other infections which may run a low grade course obviously may resemble some aspects of rheumatic carditis The correct diagnosis usually becomes clear however, as the course of disease is followed

Inactive Rheumatic Heart Disease This is not often simulated by other diseases but any cardiac affection associated with the presence of a diastolic apical murmur can cause diagnostic uncertainty The most *common difficulty is that presented by the patient with aortic insufficiency* plus an apical diastolic murmur, in whom one must decide whether the patient has rheumatic heart disease with aortic and mitral valvular deformities or *syphilitic heart disease* with aortic insufficiency plus an Austin Flint murmur at the apex Roentgenologic evidence of left auricular enlargement points to rheumatic heart disease but if this is lacking the negative finding gives little information Not infrequently one must fall back on probabilities and watching the course of disease

Occasionally, also *congenital lesions* are difficult to differentiate from rheumatic ones In addition we have encountered diastolic murmurs like that of mitral stenosis in disease of the pulmonary artery (Wyckoff and Bunim, 1935) and in sarcoma of the heart with encroachment on the mitral ring

PROGNOSIS

In discussing prognosis we must consider not only rheumatic heart disease but also rheumatic fever and each of these must be examined from the standpoint of the immediate attack and of the ultimate out come In general however rheumatic fever and rheumatic heart disease can be discussed together and any differences can be pointed out indi vidually

The Immediate Attack *The mortality for acute attacks of rheu* matic fever has been recorded as from one to four per cent in patients whose hearts have not been seriously damaged by previous attacks In a recent analysis of initial attacks of rheumatic fever (DeLiee Dodge and McEwen 1939) there were no deaths among 67 adults but the mortality

among 251 children was 1.2 per cent. Furthermore, when the children who had chorea as their only manifestation of rheumatic fever were excluded, this figure rose to 2.6 per cent, while in the 70 who had definite carditis the mortality was 4.3 per cent. Of the three children in this small series who died, all had subcutaneous nodules and all had definite evidence of pericarditis. This is in keeping with the general impression that *these two manifestations are apt to be of serious prognostic significance.* On the other hand, subcutaneous nodules and pericarditis do not always indicate a severe type of carditis as is shown by the fact that occasionally patients recover without any residual signs of heart damage, although such patients usually suffer permanent cardiac injury in subsequent attacks. Formerly, a hyperpyrexic type of rheumatic fever sometimes caused death before cardiac damage was important, but this type is now rare, and *today, when death occurs in rheumatic fever it is due primarily to the carditis.*

Ultimate Outcome: In view of the tendency for a patient who has once been the subject of rheumatic fever to suffer subsequent attacks in each of which the heart sustains additional damage, it is easy to see that the ultimate prognosis in rheumatic fever and rheumatic heart disease is very different from that in a disease like pneumonia, for example, *in which prognosis is almost entirely a matter of the immediate attack.*

Fortunately many patients with rheumatic fever recover completely. Among 683 children followed by Findlay (1931), approximately 30 per cent showed no evidence of cardiac disease at any time or developed signs which later disappeared. Similar results were recorded by Coombs (1924) and Edstrom (1935), 25 per cent and 20 per cent respectively of whose patients made complete recoveries. On the other hand, *once rheumatic heart disease has developed, prognosis is less good.* Thus DeGraff and Lingg (1935a), analyzing the records of 644 patients with rheumatic heart disease who had been followed up to the time of death, found that three fourths of them died before the age of 40. The average patient had suffered his original rheumatic attack at the age of 17, developed the first signs of diminished cardiac reserve at 28, had definite heart failure at 30 and died at 33.

The fundamental differences in resistance and susceptibility of various individuals which make one person prone to serious and repeated attacks of rheumatic fever while another escapes, are hidden in the same obscur

ity which clouds the etiology of the disease However, some factors are sufficiently definite to warrant discussion

Age at Onset This factor seems to be different for rheumatic fever and rheumatic heart disease DeLiee Dodge and McEwen (1939) found that only 30 per cent of 67 adults showed signs of carditis during their first attacks of rheumatic fever and that in only seven per cent was there evidence of persisting cardiac damage by the time of discharge from the hospital In 78 children on the other hand these figures were respectively 16 per cent and 27 per cent Findlay (1931) has shown the same tendency for life expectancy in patients experiencing their first attacks of rheumatic fever in these two age periods However if one studies not attacks of rheumatic fever but only those in which the heart is involved quite different results have been obtained Thus in the 644 patients with rheumatic heart disease followed by DeGraff and Lingg (1935a), the total duration of life following the first attack of carditis was greater when that attack occurred in childhood than when it occurred later

Type of Manifestation Another very important factor in the prognosis of rheumatic fever is the type of rheumatic manifestation which the individual patient has In patients with subcutaneous nodules or with carditis without other manifestations severe and permanent cardiac damage is apt to occur Chorea is least prone to be followed by important cardiac disease and polyarthritis stands between these two extremes Sutton and Dodge (1938) who followed a group of children six years or longer *reported an incidence of permanent heart disease of 18 6 per cent* in those with pure chorea compared with 72 per cent among children with other rheumatic manifestations Similar tendencies have been shown by other studies (Findlay 1931 Jones and Bland 1935 Ash, 1936 DeLiee Dodge and McEwen 1939 etc)

Sex The influence of sex on prognosis has been studied with conflicting results and probably is unimportant Cabot (1926) found the duration of life shorter in men than in women with rheumatic heart disease while Findlay (1931) on the contrary estimated the death rate *to be ten times the normal expectancy among rheumatic boys and 12 times* the normal among rheumatic girls Probably the correct answer is reflected in results of Friedberg and Tartakower (1931) and *DeGraff* and Lingg (1935a) who found no difference as to life expectancy between the two sexes

Auricular Fibrillation This arrhythmia is of serious prognostic significance when permanent but not in its paroxysmal form In DeGraff and Lingg s (1935c) series 34 per cent of rheumatic cardiac patients died within one year of the onset of permanent auricular fibrillation and 75 per cent within three years These are average figures however and some patients live many years

Severity of the Attack It has often been said that the more severe the symptoms of a given attack of rheumatic fever are the greater is the probability of severe cardiac crippling Possibly this is true in cases starting with polyarthritis as the principal manifestation but there can be no doubt that serious cardiac damage often is found in individuals who have had such mild attacks of rheumatic fever that the latter passed unnoticed In the author s clinic at Bellevue Hospital for example 19 per cent of the patients with mitral stenosis gave no history of any rheumatic manifestation in spite of close questioning and in an additional 13 per cent there was a history merely of vague symptoms which per se would not have warranted a diagnosis of rheumatic fever Since this is an adult clinic it is probable that some of these patients had had rheumatic attacks in childhood which they had forgotten but others must have had such ill defined attacks that they escaped notice

Case Report I Patient H D a 15 year-old German American boy was admitted to the hospital on November 26 1929 because of a markedly inflamed throat One sister had had rheumatic fever in 1926 but his parents and two other siblings were normal

The patient s first attack of rheumatic fever occurred in 1928 when he was in bed at home for three weeks with characteristic polyarthritis but he knew nothing of heart involvement His second attack occurred in April 1929 at which time he was admitted to the hospital where he remained until August During that attack he had polyarthritis carditis pleuritis and iritis There were both systolic and diastolic murmurs at the apex but at the time of discharge in August all evidence of rheumatic activity had disappeared as had the diastolic murmur He was seen a few months later at a follow up examination and appeared to be normal in every way There was no cardiac enlargement and merely a blowing systolic murmur at the apex

Tonsillectomy had been performed during the first admission but he had been warned that throat infection might lead to further rheumatic attacks In view of this he reported back to the hospital on November 26 1929 because of a sore throat This infection had begun on November

17 and was associated with sufficient fever and soreness in the throat to cause him to stay home from school for several days He had then felt perfectly well again However, on November 25, his throat again became painful and he reported to the hospital the next day This time the throat was markedly inflamed and he was advised to stay in the hospital, not because of any evidence of rheumatic fever but because a peritonsillar abscess was suspected Physical examination of the heart revealed nothing abnormal even the faint systolic apical murmur having disappeared Throat cultures revealed no hemolytic streptococci and several blood cultures were negative Leukocyte count showed 10 840 leukocytes with 68 per cent polymorphonuclear cells 28 per cent lymphocytes, and 4 per cent monocytes

By November 29 the sore throat had cleared and it was decided that the patient might return home the next day Later the same day, however, the apical systolic murmur again became audible and the temperature and pulse which had been normal rose slightly For this reason hospitalization was continued and the patient was observed carefully for possible reactivation of his rheumatic carditis In the following days various abnormal findings appeared in sequence Temperature and pulse continued to rise T waves in Lead III of the electrocardiogram became negative leukocyte count rose to 15 800, pulse rate became disproportionate to the moderate fever, a presystolic blowing murmur appeared at the apex, and a few days later an early diastolic blow was audible along the left sternal border at the level of the second and third intercostal spaces, gallop was heard at the apex there was a progressive striking increase in atrioventricular conduction time, reaching a peak of 0 25 sec., and roentgenologic as well as clinical studies revealed slight cardiac enlargement Temperature and pulse then gradually fell to normal, the latter more slowly than the former the electrocardiogram became normal, and both apical and basal diastolic murmurs disappeared This whole episode from the time the temperature first rose on November 29, covered approximately four weeks Improvement was then steady, so that the patient was discharged on January 30 with the same diagnosis as previously carried

This patient returned one year later with his fourth attack of rheumatic carditis and this time the evidence of mitral stenosis and aortic insufficiency returned promptly and has persisted to date

Comment This report (of the patient s third attack) is presented as an example of carditis as the only manifestation of rheumatic fever. The striking feature of the case was the lack of subjective symptoms for the patient insisted that he had no complaint other than the preliminary sore throat and that when that cleared he would not have known he was

sick if he had not been told Attacks of carditis of this type probably occur relatively frequently in children who are not under medical supervision and account for a certain number of cases of obviously advanced inactive rheumatic heart disease in patients who can recall no attack of rheumatic fever.

Recurrent Activity. The factor of fundamental importance in the prognosis of rheumatic heart disease is, of course, the degree of damage caused by active cardiac involvement, or in other words, the severity of the first attack of carditis and the frequency and severity of recurrent attacks. The patient with one attack which clears promptly and who never experiences another, has an essentially normal life expectancy; while the expectancy obviously is very different in the patient with repeated attacks, in each of which progressive cardiac crippling is sustained. Unfortunately, the mechanism of resistance and infection underlying these differences is too incompletely understood to enable one to prognosticate in the average case. However, it is true that successive attacks of rheumatic fever tend to follow a given pattern in each individual patient, so that a patient who has had several attacks without developing apparent cardiac damage has a reasonable expectancy of again escaping it at subsequent attacks.

TREATMENT

In discussing the treatment of rheumatic heart disease it is convenient to consider carditis and the inactive stage separately. Obviously, too, attention must be given to the treatment of some of the other rheumatic manifestations and of rheumatic fever in general.

Treatment of Carditis: *Of primary importance in working out a* program for the treatment of patients with carditis is the appreciation that this phase of rheumatic heart disease is an *infection* More important than symptomatic care, therefore, are efforts directed toward helping the patient overcome the infection. Unfortunately no specific means of combating rheumatic infection are known and one can merely institute those measures which help the patient to overcome his own disease While the basic principles of treating carditis are the same for all stages, some of the details in the management of the acute phase differ from those of the subacute and chronic. In the past the more spectacular character of the acute phase has focused chief attention on it, but today we are equally concerned with subacute and chronic rheumatic carditis. In this account,

the treatment of these stages is discussed separately, following which there is brief consideration of special therapeutic methods, of the treatment of inactive rheumatic heart disease, and of preventive measures.

Acute Carditis: GENERAL CARE: The patient with acute carditis usually has high fever and sweating and should be protected from direct drafts. When sweating is profuse, comfort can be increased by the use of wool or flannelette sheets and clothing, the latter of which should be of a type easy to put on and off. Frequent bathing and alcohol sponges are helpful in keeping the skin in good condition, but this is more important in the chronic than in the acute stage.

Rest is of the utmost importance. In acute carditis the patient feels so sick that one does not face the problem of enforcing bed rest, which often becomes so difficult later in the disease; but rest is often interfered with by cardiac and arthritic pain and by such symptoms of heart failure as dyspnea and orthopnea.

Cardiac pain usually is helped by an ice cap applied to the precordium. If this is not sufficient, codeine should be given in doses large enough to give relief. Even children five or six years old may be given 0.03 Gm. (½ grain) of codeine sulfate every three or four hours if smaller doses are not effective. Rarely morphine is required. Amyl nitrite and the antirheumatic drugs have no effect on the pain of carditis, although the former is helpful in the true anginal type of pain which sometimes occurs in patients with long-standing aortic insufficiency and stenosis, and the latter, of course, are invaluable in the relief of arthritic pain.

DIET: During acute carditis the patient usually is too uncomfortable to care much for food and should not be forced to eat. Light foods, especially in liquid form, are sufficient if the acute phase does not last more than a week. If the patient's appetite does not improve then, however, greater efforts to induce adequate intake of calories and vitamins are required to prevent undernutrition. Large amounts of fluids commonly are given to make up for loss due to sweating and to aid in the elimination of waste products through the kidneys, but if heart failure with edema develops the fluid and salt intake should be curtailed.

ANTIRHEUMATIC DRUGS: It has been proven repeatedly that the various antirheumatic drugs do not have any effect on rheumatic lesions in the heart, in contrast to their dramatic effect on the joint manifestations and fever. On the other hand, we believe these drugs may be help-

ful in easing the burden of the over-acting heart by relieving that part of the tachycardia which is due to fever and toxemia. Sodium salicylate, acetylsalicylic acid or neocinchophen may be given to adults in doses of 1 Gm. (15 grains) every hour for nine or ten doses unless symptoms of toxicity appear. After several days this dose can be decreased gradually. Aminopyrine is effective in doses of 0.3 Gm. (5 grains) four to six times daily and has the virtue of seldom causing nausea in therapeutic doses. Patients receiving it must be watched with special care, however, because of the possibility of agranulocytosis developing from its use. In treating children the amount of whatever drug is chosen is reduced in accordance with age.

While appreciating what these drugs can do to make the rheumatic patient more comfortable, the physician should be equally aware of their shortcomings and recognize that they have no effect in lessening the severity or duration of the inflammatory changes in the heart.

DIGITALIS. The statement is sometimes made that digitalis is contraindicated in carditis. In our opinion this view is entirely unjustified, and we have found it extremely valuable in both the acute and chronic phases of rheumatic heart disease. As in the case of heart disease of other etiological types, digitalis is indicated chiefly in the treatment of heart failure and auricular fibrillation, but it sometimes has seemed beneficial in the absence of these if the heart rate exceeds 110. The tablets of powdered leaf are easy to use and are usually standardized in such a way that each 0.1 Gm. (1½ grain) equals 1 cat unit. A convenient method of administration is to give an initial dose of 4 cat units, followed by 2 cat units six hours later, and then by 2 cat units morning and afternoon until a therapeutic effect or the earliest symptoms of digitalis toxicity appear. A daily maintenance dose of 1 or 2 cat units usually suffices thereafter.

While we believe digitalis to be extremely useful in carditis associated with heart failure, we believe, too, that in rheumatic carditis, perhaps more than in most other etiological types of heart disease, it is important to avoid giving the drug to the point of such frank toxicity as vomiting and coupling. If carditis is severe enough, digitalization is ineffective and the failure of the patient to respond may result in the dosage being increased until the vomiting of toxicity is added to that of visceral con

gestion Therefore *patients with carditis receiving digitalis must be* watched with special care for evidence of digitalis toxicity

SULFANILAMIDE Because of the apparent connection between hemo lytic streptococcal infection and rheumatic fever it is natural that sulfanilamide has been tried in the treatment of the latter Recent investigations (Swift Moen and Hirst, 1938 Coburn 1938 Jones 1938), however are in complete agreement that the drug is useless in the treat ment of established rheumatic fever Indeed there is evidence that it may make the disease worse Its use in prophylaxis is discussed later

Pericarditis This component of carditis needs special comment because it may require treatment different from that of carditis in gen eral if effusion becomes large Even moderate accumulations may add to respiratory embarrassment and massive effusion rarely may cause death by cardiac tampanade As a rule no special treatment is required but if dyspnea becomes troublesome pericardial paracentesis should be per formed *Before doing so one must be as sure as is possible that the* dyspnea increased area of cardiac dullness and roentgenologic findings are actually due to massive pericardial effusion because cardiac dilatation can simulate them almost exactly In adults the anterior approach may *be required but in children in whom aspiration is most apt to be* required the pericardium can be tapped easily from behind (Sutton 1934) As much fluid should be withdrawn as can be obtained without difficulty unless the patient develops untoward symptoms An indication for immediate aspiration is a sudden fall in blood pressure in a patient with a massive effusion suggesting as it does cardiac tampanade

Subacute and Chronic Carditis It is thoroughly appreciated today that although much less dramatic than acute carditis the stage of sub acute and chronic cardiac inflammation is at least as important All patients who have had acute carditis pass through the subacute phase during recovery but many others experience it without ever having had the acute disease The care required is prolonged and consists of rest good food supportive medication suitable climate and the avoidance of intercurrent respiratory infections

REST Of all treatment advocated in carditis rest remains the most important Not infrequently the physician faces a difficult problem because the patient usually feels quite well and desires to get out of bed before his disease has become inactive In spite of his apparent well

being, however certain requirements should be met before he is allowed out of bed These are normal temperature pulse and leukocyte count for at least ten consecutive days in the absence of antirheumatic drugs freedom from all manifestations of active rheumatism such as joint pain subcutaneous nodules and erythema marginatum normal auriculoventricular conduction time *erythrocyte sedimentation rate within or very close to normal limits* a satisfactory weight curve and good general condition When recovery has occurred to this extent the patient may sit up for a gradually increasing period each day and finally may cautiously begin walking and later stair climbing If at any time a setback occurs exercise must be held constant or the patient may even have to return to bed

If the pulse remains rapid when all other signs are favorable the rate should be counted while the patient is sleeping for not infrequently tachycardia in these convalescent patients especially children has a psychogenic cause and the heart rate is normal during sleep This psychogenic reaction is not surprising since these children are apt to become highly introspective during their long period of invalidism unless care is taken to prevent it Intelligent management by the patient s nurses and parents is therefore extremely important and various forms of occupational therapy of great aid

Diet In the subacute and chronic stage diet should be varied appetizing and sufficiently high in caloric value to cause gradual gain in weight These patients usually show a very satisfactory rise in the weight curve if the course of disease is satisfactory and indeed over weight may even require reduction in the amount of food during con valescence On more or less empiric grounds diets high in vitamins A and C are usually advised

Drugs Secondary (hypochromic microcytic) *anemia* usually is pres ent and unless combated therapeutically is apt to be progressive until well on into convalescence Iron *is the drug of choice for this although* rarely transfusions *are indicated Ferrous sulfate in doses of o 3 Gm* (5 grains) t i d is a very *satisfactory form of iron for this purpose*

Cod liver oil is often given as a general supportive measure If used the whole oil is probably best since there is no evident lack of vitamin A or D and what value it has may be due to he additional calories supplied

Many of these patients require mild laxatives because of debility and long confinement to bed

Treatment of Convalescence This is merely a continuation of rest nourishing food general care and medical supervision combined with gradual increase of daily activities until the customary mode of life has been resumed Many patients can obtain this type of care in their own homes but rheumatic fever is essentially a disease of the poor who often must return from the hospital to crowded and unhygienic conditions When openings are available such patients usually are sent to convalescent homes but these while excellent for patients whose disease has become completely inactive usually require too much exercise for those with persistent low-grade activity There is need therefore for more sanatoria for the care of convalescent rheumatic cardiacs similar to those provided for patients with tuberculosis While some institutions of this type are now in operation the program of construction lags far behind that of tuberculosis sanatoria As rheumatic hospitals and sanatoria are built however it is important that careful study of their usefulness be made for there is no certainty as yet of their ultimate value Thus several studies (McCulloch and Irvine Jones 1929 Halsey 1938) indicate that a sojourn in even the best convalescent hospitals for rheumatic cardiac children does not decrease a child s susceptibility to recurrent attacks of rheumatic fever after return home Stroud (1933 and 1939) on the basis of his extensive experience at the Philadelphia Children s Heart Hospital is convinced that children with low grade active rheumatic carditis are benefited during convalescence there but in a 15 year follow up study of such children he found the mortality figures over that period of time to be about the same as for similar children given convalescent care in their own homes It is pointed out below that tropical and subtropical climates seem particularly beneficial to rheumatic subjects and it may be that in the future sanatoria in such suitable climates will prove to be of especial importance in the treatment of this disease

Climatotherapy Many studies have shown that rheumatic fever is much less common in the tropics than in northern climates Because of this Coburn (1931) transported a group of rheumatic children from New York to Puerto Rico and found that they did very well while there but soon developed rheumatic relapses after return home Jones White

Roche, Perdue and Ryan (1937) have made a more extensive study of a group transported from Boston to Miami, but obtained much less striking results. Nevertheless, *it is probable that climatotherapy has an important place in rheumatic fever,* although the good results are apt to be temporary unless the patient remains in the new environment. The explanation of this beneficial effect is not known with certainty, but it probably is the same factor that causes improvement in rheumatic subjects during the summer and early fall in the northern states.

Eradication of Focal Infection: In spite of much discussion of tonsillectomy in the treatment of rheumatic fever, its value remains in doubt. A few of those advocating tonsillectomy recommend that it be done early in the acute phase of disease in the hope of preventing serious cardiac damage (Robey and Finland, 1930), but the majority believe operation at this stage to be dangerous and do not attempt it until the patient is convalescent. Statistical study of the ultimate value of tonsillectomy in rheumatic fever is disappointing. Wilson, Lingg and Croxford (1928), Hill (1928-29), Ash (1938) and others, have compared the incidence of rheumatic relapses among children who have had their tonsils removed and those who have not and have found no significant difference. Kaiser's (1932) study of 48,000 school children suggests that tonsillectomy has no effect on the course of disease in those who have previously been the subject of rheumatism, but that it tends to lower the attack rate of rheumatic fever among those who have not already had it. Even less is known about the value of treating infected teeth and sinuses. It is our practice, therefore, *not to urge tonsillectomy and similar procedures as routine measures in treating rheumatic fever, but to consider each patient as an individual problem.*

Treatment with Serums and Vaccines: As early as 1902, Menzer advocated the use of an antiserum in the treatment of rheumatic fever. This idea was revived in 1927 by Small, who prepared an antiserum against an indifferent streptococcus which he called *Streptococcus cardioarthritidis.* Subsequent controlled studies using various antistreptococcal serums (Hitchcock, McEwen and Swift, 1930; Coburn, 1931 and 1935; Wilson, 1930) have shown such therapy to have no value.

Vaccines likewise have been disappointing. The theory that rheumatic fever might be due to hypersensitivity to streptococci (Swift, Derick and Hitchcock, 1928) led to studies of the possibility of desensitizing

rheumatic subjects with streptococcal vaccines (Swift, Hitchcock, Derick and McEwen 1930) *Early clinical observations suggested that the procedure might be of value* (Swift and Wilson 1931 Collis and Sheldon 1932), but subsequent study did not bear this out (Wilson Joseph and Lang 1933 McEwen and DeLiee 1936), for treated subjects fared no better than untreated controls

Fever Therapy Sutton (Sutton 1931 Sutton and Dodge, 1933 and 1936) has shown that chorea clears up rapidly under the influence of fever therapy Recently (Sutton and Dodge 1938) a comparative study of chorea patients treated and untreated with fever therapy has suggested *that this form of treatment may have a beneficial effect on the severity of* subsequent rheumatic cardiac lesions The usefulness of this procedure in patients with carditis is obviously still in the experimental stage and should not be attempted in general practice because of the dangers involved If subsequent work is confirmatory however, it may prove of value in carditis as well as in chorea

Treatment of Inactive Rheumatic Heart Disease Patients with inactive rheumatic heart disease may have no complaints of any kind or may have varying degrees of diminished cardiac reserve up to frank heart failure even at rest Those without symptoms even though they may have definite physical signs of valvular damage require no treatment other than occasional check up by the physician and general measures to keep them in the best possible health *If there is no diminution of reserve physical activity should not be limited with the possible exception of the most violent sports and the heaviest labor* In the case of introspective individuals care must be taken to prevent the development of anxiety states leading to psychoneuroses

If symptoms and signs of congestive heart failure appear treatment is like that of failure in any other type of heart disease (see Chapter XXXV) with the exception that a new attack of active carditis must be carefully looked for and if present the patient must have rest not only until failure has cleared but also until all evidence of active disease has disappeared

Prevention Because of the uncertainty regarding the etiology of rheumatic fever it is obvious that a discussion of its prevention must be unsatisfactory Several factors appear to be important however, and will *be considered briefly*

Avoidance of Infection Although the mechanism remains in doubt there is little question today that infection by hemolytic streptococci and possibly by other microorganisms is liable to be followed by rheumatic fever in susceptible individuals Every effort should be made therefore to protect those known to be susceptible The patient s family must be made thoroughly aware that what is just a sore throat to them may mean another attack of rheumatic fever to him and must be taught how to avoid spread of infection from other members to the patient Such instruction should include the technic of avoiding droplet infection and of sterlizing dishes used in common by the patient and those with colds and sore throats In hospitals one must be constantly watchful lest a patient with rheumatic heart disease be placed next to one with hemolytic streptococcal infection and visitors and attendants with such infection should be excluded from the wards

Tonsillectomy would seem to be a rational preventive measure in lessening susceptibility to throat infections but as has already been mentioned Kaiser s (1930) results indicate that if it is to be of help it must be done before the first rheumatic attack It is probably advisable therefore in children with a rheumatic family history who are subject to sore throats

Drug therapy as a preventive measure has offered little promise in the past Poynton and Schlesinger in 1931 reported that the administration of sodium salicylate to rheumatic subjects during upper respiratory infections and for several weeks thereafter would prevent rheumatic relapses but the experience of others has not corroborated this Recently the introduction of sulfanilamide has offered new promise Administration of the drug once a hemolytic streptococcal sore throat has started has not prevented rheumatic recrudescences (Coburn 1938) but there is suggestive evidence that daily administration throughout the year will reduce the incidence of relapses in rheumatic subjects by preventing hemolytic streptococcal infection (Coburn 1938) This use of the drug is still in the experimental stage and should be tried at present only in the case of patients in hospitals where careful clinical and laboratory observations can be made Obviously it will be extremely important if further study proves the preliminary work to be correct

Immunization against rheumatic fever and hemolytic streptococcal infections by means of vaccines has been unsuccessful to date

Climatotherapy Although considered separately it is very possible that climatotherapy also acts by preventing upper respiratory infection From what has already been said about the beneficial results obtained by transporting rheumatic fever patients to the tropics (Coburn 1931), its usefulness in preventing recurrent rheumatic attacks seems obvious For those who can afford it and who do not wish to remain permanently in the tropics sojourn there during the months when rheumatic fever is most prevalent (November through May for the United States) would appear to be reasonable

General Hygiene Finally it is obvious that any measures such as good housing, sunlight good food fresh air and exercise which tend to improve the patient s general health and exert a beneficial effect on his resistance to infection in general must also be of importance in the prevention of rheumatic fever

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CHAPTER IV

THE EPIDEMIOLOGY OF RHEUMATIC FEVER

By John R. Paul, M.D.

GENERAL PREVALENCE

The prevalence of rheumatic fever and its most serious manifestation, rheumatic heart disease, is conditioned by many factors. On the one hand there are those of climate, geographical location and living conditions; and, on the other, there seems to be a predisposition to the disease, which is hereditary. Consequently, broad statements about general prevalence are not particularly informative, but we can at least say that it is one of the most important and most common infectious diseases in this country. The same may also apply to all of the temperate regions in the world And yet, as it is a reportable disease only in a few countries and small communities, exact prevalence or incidence figures are generally not available The problem might be simpler if all that we wished to know were the case rates, and the death rates of the acute phase of the disease. But, unfortunately, the real significance of rheumatic fever lies not in the acute illness it produces, but in its chronicity, its tendency to recur, and in its healed residual lesions. The best we can generally do, therefore, is to estimate this on the basis of clinical experience in different regions To begin, we may turn hopefully to some of the surveys of *hospital admission rates* for active rheumatic fever throughout the world, and in this country.[1, 2, 3, 4] These rates show a significant difference in prevalence in different regions and climates, with an apparent decrease in the prevalence of the disease in tropical and subtropical regions. In temperate climates the hospital admission rates for active rheumatic fever may reach impressive figures, ranging from about one to three per cent of all admissions. If both active and inactive forms of the disease are included, these admission rates may be as high as from three to seven per cent, which is a figure mentioned by Swift[5] for large general hospitals

in Europe and the United States It would thus seem that in temperate climates at least the prevalence of the disease lies not far behind that of the two commonest chronic infections namely tuberculosis and syphilis

Another method of measuring the prevalence of rheumatic fever although it is a less direct one lies on determining the prevalence of *inactive rheumatic heart disease or in other words the heart disease rates* in groups of young people In the United States such estimates have been made from heart disease surveys upon groups of young adults which include college students[6] men drafted for military service[7] and groups of industrial workers[8] In these adult groups rheumatic heart *disease has been found to be present in from 0 8 to 2 0 per cent of those* examined More informative data have however been obtained from similar surveys upon groups of school children[9] By and large the school children groups furnish a better cross section of the local population than do adult workmen and at present at least they offer the best source of *reliable information about the actual prevalence of rheumatic heart dis*ease in different localities Surveys from Europe England[9] South Africa[9] and Australia[10] list rheumatic heart disease as occurring in from 0 1 to 2 0 per cent of the school populations In this country similar estimates from the cities of Boston New York Chicago[9] Philadelphia[9 11] and *others furnish us with rates ranging from 0 5 to 1 4 per cent Occa*sionally higher figures have been found when heart lesions have been searched for with particular care Among Indian school children in the western part of this country 2 0 per cent of 2800 school children examined were found to have rheumatic heart disease[12] and among 2600 school *children in New Haven Conn* the rate was 2 ? per cent[9] *It is the* author s opinion that we may not be far wrong in saying that almost 2 0 per cent of the grade school children throughout the northern part of this country have rheumatic heart disease This sounds alarmingly high but it does not follow *that all children in whom rheumatic heart disease is detected* between the ages of 7 and 14 will continue to show signs of this condition for the rest of their lives In fact it now seems definite from the observations of Ehler[13] and of Bland Jones and White[14] that in some of these children the signs of heart disease eventually disappear Particularly *is this apt to occur about the age of* puberty It is unlikely of course that the lesions of rheumatic heart disease completely disappear as well as the signs but it would seem at least

as if such cases would pass into the category of subclinical rheumatic heart disease, and, as such they should not be included among clinical prevalence estimates

And, finally, from *mortality statistics* some information may be derived about the general prevalence of rheumatic fever and carditis In this connection it should be recalled that rheumatic fever produces a high degree of morbidity but a low acute mortality In fact, if all age groups are considered, death is said to occur in less than one per cent of the so-called acute cases On the other hand, if, as was done by Glover[15] in England, an age group between 10 and 15 is taken (the age at which the disease is most acutely fatal, with a mortality in hospitals occasionally reaching 13 per cent), it has been found that rheumatic fever causes 5 4 per cent of all deaths, and heart disease (80 per cent of which at this period is due to rheumatic fever), 10 8 per cent, or a total of 16 2, four fifths as much as all forms of tuberculosis and more than twice as much as measles scarlet fever, and diphtheria combined Among adults, an analysis of mortality rates for this condition should also include *old* rheumatic heart disease Statistically speaking, old rheumatic heart disease has, for many years, been buried under the unqualified term, heart disease, and the older the patient becomes, the deeper is the grave, so the task of the analyst is not easy [16a] Recently, however, a valuable contribution to the mortality rate of rheumatic heart disease has been made by Hedley who carefully collected data from the city of Philadelphia during the year 1936 [16b] Old and inactive cases of rheumatic heart disease, subacute bacterial endocarditis superimposed on rheumatic heart disease, rheumatic fever and chorea were all included among his causes of death attributable to rheumatic fever From this survey he estimated that the total mortality from rheumatic heart disease was 25 to 30 per 100 000 In comparing this with other infectious diseases, it is thus found that rheumatic heart disease was exceeded as a cause of death only by tuberculosis lobar pneumonia and syphilis Among the essentially chronic infectious diseases it ranked third, exceeded only by tuberculosis and syphilis This more or less substantiates the impression gained from morbidity surveys of hospital admission rates for rheumatic fever and carditis, mentioned earlier in this article We can reiterate, therefore, with some confidence that rheumatic fever is one of our most important and common diseases

BACTERIOLOGY

No attempt will be made to review the enormous literature dealing with the search for a *specific bacterial incitant in rheumatic fever*, for this subject would really warrant a special chapter More attention has been paid to streptococci than to other types of bacteria and in brief it can be said that most workers investigating the cause of rheumatic fever *seem to have been forced at some time to a consideration of the role which* they may play The association between *Streptococcus hemolyticus* infections of the upper respiratory passages and rheumatic fever is indeed strong, for a high percentage of acute attacks of the latter disease seem *to be initiated by such infections Such infections include those of acute* tonsillitis scarlet fever otitis and sinusitis to mention but a few It is a common observation to see signs of either a primary or a recurrent attack of rheumatic fever appearing close upon the heels of one of these *streptococcus infections This phenomenon has been studied extensively* by Coburn [17] to whom much of our knowledge about the situation is due

In keeping with this same concept of the pathogenesis of rheumatic fever is the epidemiological evidence of its association with hemolytic *streptococcus infections* Atwater[18] and Rosenau[19] have *pointed out* that parallelism seems to exist between the incidence of rheumatic fever and the incidence of streptococcus diseases that a good year for streptococcus diseases is a good year for rheumatic fever Still more informative data *have recently come from* Denmark where rheumatic fever is a reportable disease Here Madsen[20] has found that the seasonal incidence curve for rheumatic fever and that for tonsillitis scarlet fever and erysipelas are of essentially the same type But the peak for streptococcus infections is sharper and is reached in November which is two months earlier than the peak for rheumatic fever which occurs in January and follows a flatter curve

Nevertheless in spite of suggestive *clinical* and epidemiological evidence which points an incriminating finger towards the hemolytic streptococcus most students of this subject agree that for an adequate understanding of the cause of rheumatic fever other things must be considered besides this bacteriological agent *Certainly it is but a small percentage* of patients infected by this organism which develop clinical rheumatic fever There is more to the problem than mere contact between the host and this parasite But whether rheumatic fever represents a peculiar

immunological response to streptococcus infections which is perhaps conditioned by environmental factors, or whether streptococcus infections merely activate another condition which may be latent in the host, or whether patients with rheumatic fever are peculiarly susceptible (perhaps on an hereditary basis) to infections by the streptococcus, are unanswered questions. It would, indeed, seem that there must be certain important factors standing between the host and parasite, so to speak, and that perhaps the *nature of susceptibility* represents one of the greatest problems which demands solution if a better appreciation of the pathogenesis of this disease is to be gained.

PREDISPOSING CAUSES

1. General: (a) *Sex:* Among children it has been the general experience that girls are more frequently affected than boys in a ratio of about 60 to 40 per cent, respectively. In hospital cases, embracing all ages, there is approximately an equal division between the sexes.

(b) *Age:* In its familiar forms, rheumatic fever is a disease of childhood and young adult life. From a clinical standpoint, the acute forms are uncommon after 40 or 45. It is also rare in infants under two years. About 40 cases have been reported in infants under one year of age, most of whom were being nursed by mothers suffering from acute phases of the disease.

It is probable that many of the juvenile forms of the disease, particularly those in which joint symptoms were absent or minimal, have gone unrecognized, so that much of the older data on the age incidence are inaccurate. Furthermore, owing to a peculiar tendency for the recurrence of acute attacks of this disease, all statistical data on the age incidence should be viewed critically as to whether only primary, or primary and recurrent attacks are included. It should also be known whether the patients in any given series represent a selected group. In Rolly's[21] series of 1450 cases, for instance, collected in 1920 in Leipzig, which included both *primary and recurrent* attacks, 75 per cent of such attacks occurred between the ages of 15 and 30, the largest number being found at the age of 18! On the other hand, in Mackie's[22] series of 40 cases, collected in New York City, in which only *primary attacks* were included, the greatest number of cases occurred between 10 and 15 years of age. Wilson, Lingg and Croxford[23] place the maximum incidence of initial attacks

at still an earlier age, stating that in a series of 113 children attending cardiac clinics in New York City, 98.4 per cent occurred before the age of 15 the average age at onset being 7.3 years These investigators and others[24, 25] believe that susceptibility to the infection begins to diminish about or before the age of 12 This diminishing susceptibility which proceeds during and immediately after the years of puberty is a feature of clinical as well as epidemiological significance Reference has already been made in this article to the fact that clinical signs of rheumatic carditis may regress during this period (puberty) and that this fact is of sufficient numerical importance to warrant its consideration when heart disease rates are being determined among school children of different age groups Obviously it also has an important clinical bearing upon questions of prognosis and treatment of the adolescent rheumatic patient

2 Environmental (a) *Geographical* and *Climatologic* The disease is widespread throughout the world although it seems to be a fairly well established fact that it is less common and less severe in the tropics as compared with temperate climates simulating in this respect scarlet fever Clarke[26] who reviewed the geographical distribution of the disease states that according to the returns of medical departments there is about 15 times as much rheumatic fever in temperate climates as there is in the tropics But the rarity of rheumatic fever in certain parts of the world should be accepted with caution for the disease is often readily overlooked Dieuaide[27] has pointed out that the disease was thought to be rare in China but this did not prove to be true of Peiping when they began to look for it Nevertheless many agree that rheumatic fever maintains an unusually high incidence in England As already mentioned hospital statistics from North America record a higher incidence of the disease in the North and Middle Atlantic states and Canada as opposed to the Southern states[1, 2, 3, 4] Paralleling this decrease in rheumatic fever in the South there is also found a decrease in rheumatic heart disease according to observations from Florida[4, 28] Another example of this may be found in a recent study of the prevalence of rheumatic carditis among Indian school children in the West, where it was found to be almost ten times as prevalent in the Northwest as in the Southwest[12]

Closely associated with geographical location is the question of climate[29] We find that the acute stages of illness follow a distinct seasonal trend which seems to differ in different localities although the greatest

number of acute attacks generally occur in the colder and wetter months of the year In England rheumatic fever is generally more prevalent in the Fall in Denmark in Midwinter[20] In the eastern part of the United States it reaches a maximum incidence during the late Winter and early Spring months[30] Cold weather in itself does not seem to be a predisposing factor for the rarity of the disease in arctic regions would support this view Cold coupled with dampness are however climatologic conditions which have been said to favor its development but although this belief has long been held attempts to analyze these factors have met with stubborn resistance In this connection attention has been called to the fact that during the World War rheumatic fever was scarce among troops in action exposed as they were to excessive cold and dampness and that the disease appeared more frequently among troops quartered in barracks Reports from German[31] French[32] and British[33] sources mention this fact

In brief therefore the situation resembles one which prevails in respiratory infectious diseases which find their highest incidence during the colder months and under situations which promote crowding within doors

(b) *Social and Living Conditions* Rheumatic fever is more prevalent among industrial and urban populations than rural ones[34] It is said to find a particularly high incidence among river front dwellings in industrial towns[35] but whatever the relationships between damp housing conditions and the incidence of rheumatic fever may be it must be an indirect one Poverty and its attendant conditions seem to furnish favorable soil for its development and in England the statement has been made that the disease occurs perhaps 20 to 30 times more frequently among poorer children of industrial towns than among children of the well-to-do[15] Among well to do school children and University students in New Haven Conn the prevalence of rheumatic heart disease was found to be considerably lower (one eighth to one half) than that found among the poorer pupils and students[9, 6] The more marked differences in the social prevalence reported in England have not however been noted in this country

Intimately related with the problem of poverty are those of malnutrition crowding uncleanliness poor ventilation and the presence of vermin All of these factors have been considered of possible importance

in the spread of the disease but the actual part which they play is unknown Possibly the situation is analogous to that seen in tuberculosis where malnutrition and poor hygienic surroundings render conditions favorable for the development and maintenance of the infection

Recent work on deficient diets in rheumatic fever which implicates a deficiency of vitamin C [36] as a factor predisposing to rheumatic fever should receive thoughtful attention It has not however been widely repeated or accepted

3 **Hereditary** (a) *Racial Susceptibility* Statistics from large hospitals in New York City in which many races are represented among their patients tend to show that the disease is more frequently encountered among patients of English Irish and Italian extraction [30] The cause of the differing incidence however is not as yet clear when it is recalled that *these figures are dependent upon many complex factors including those* which are responsible for bringing people to the hospital so that such data cannot be used to postulate that actual racial predispositions to the disease exist

(b) *Anthropological Types* Many investigators believe that certain types of individuals are peculiarly susceptible to the development of rheumatic fever [37, 38] but here again data regarding these views are somewhat conflicting [39, 40]

(c) *Familial Prevalence* The concentration of rheumatic fever within certain families has long been recognized as a prominent feature of this disease Like tuberculosis rheumatic fever is said to run in families and the degree to which this is true is about the same for the two diseases It has been shown for instance that in families in which the parents have suffered from rheumatic fever the prevalence of this disease is more than twice as high among the children than in other families Cohn states that in so-called rheumatic families eight to ten *per cent of exposed persons are infected* as against 0 9 *per cent in the* families of healthy controls [41] More recently this same general ratio has been also found by Read[42] and *her co workers in the families of a* small group of rheumatic children as opposed to those of a control group of children admitted to a tuberculosis clinic One great difficulty of comparing figures on familial incidence depends however upon the investigator s definition of what constitutes a family group as well as his criteria

for establishing the presence of rheumatic fever in those members which are *included in the family group*

The findings in identical twins are interesting in this connection and perhaps more informative Wilson and Schweitzer's[43] four pairs of identical twins were all alike in having rheumatic fever whereas of 12 pairs of fraternal twins five pairs had similar incidence and seven pairs had dissimilar incidence Similarly Kaufmann and Scheerer[44] describe 72 sets of twins with acute articular rheumatism Among their 27 sets of uniovular twins the disease was present in both five times whereas among their 45 sets of binovular twins it was present in both but once The evidence that some hereditary factor is operative in rheumatic fever becomes substantiated from these observations but its degree of importance is still undetermined Whether it is as prominent as in a disease such as asthma for instance is not known In spite of a good deal of work on this point it seems that we cannot yet improve upon the statement made by Cheadle 50 years ago that the *tendency* to rheumatism is transmitted[45]

An illustrative method[46 47] useful both for clinical purposes and for the analysis of the relative importance of hereditary and environmental factors lies in the employment of diagrams similar to those previously devised for the study of these factors in tuberculous families In Fig 1 one of these diagrams appears showing a sample rheumatic family from the *files of the New Haven Hospital and Dispensary* Charted on the vertical lines (representing different individual members of the family) are points at which rheumatic fever appeared in this family and the time and age relationships between the multiple familial cases can thus be seen at a glance From a large series of these charts one can attempt to answer the question as to how often the disease spreads horizontally (that is how often multiple familial cases are acquired more or less simultaneously) or how often the disease spreads obliquely (that is how often multiple familial cases are acquired in progression as each child reaches the age of seven or nine years let us say) From our own studies[46 47] we have concluded that multiple familial cases are usually acquired simultaneously among siblings during their age periods of greatest susceptibility to the disease outside this period the familial cases appear more at random Much work remains to be done on the familial epidemiology of this disease The results which emerge from the work to date might be summarized in a clinical statement which is that given a family with young

children in which both parents are rheumatic (that is, both either have or have had rheumatic fever) when an epidemic of *Streptococcus hemolyticus* infection occurs in this family group, there is apt to be trouble in store. In other words, regardless of the initial form in which this infection

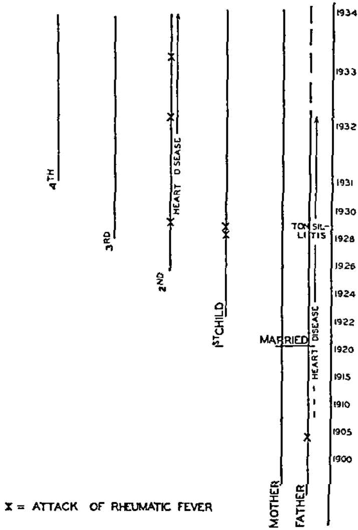

FIGURE 1 Diagram of sample family (Mn) with four children, each member being designated by a vertical line It shows that the father had rheumatic fever and carditis as a boy In 1929 he suffered from a severe sore throat of two months duration At about this time two of the children, aged seven and four respectively, had attacks of rheumatic fever, one of them accompanied by severe heart disease This simultaneous occurrence of severe, upper respiratory infections and multiple cases of rheumatic fever within families has occurred not infrequently in our studies

may manifest itself, *i e.*, tonsillitis, otitis, scarlet fever, etc , the chances are that the children will suffer from more rheumatic complications than will the children of *nonrheumatic parents.*

EPIDEMICS

These have been recorded in families,[46] houses,[48, 49, 50] barracks,[15, 32, 51, 52] schools and colleges,[53, 54, 55] and in communities.[52] Some of the accounts describe waves of increasing incidence of the disease, others explosive outbursts, in which a series of cases has been apparently initiated among (a) individuals who gave no evidence of having previously had the disease, and (b) individuals who have had the disease before. The latter situation has been described among children convalescing from subacute phases of rheumatic fever in hospital wards,[56, 57] convalescent homes,[58] and cardiac camps,[50] and the "epidemic" has generally followed an epidemic of upper respiratory infection of streptococcus origin.

We have no explanation for the epidemics of type (a). It can be pointed out, nevertheless that in any "epidemic" of hemolytic streptococcus infections, a certain percentage of those infected may contract rheumatic fever perhaps as a *"complication."* Just what this percentage is (of those who develop these 'complications') is unknown. It would depend, as has already been pointed out, upon the age of the group involved and perhaps upon the strain of streptococcus involved, for, according to Glover and Griffith,[60] different epidemics caused by different strains of *Streptococcus hemolyticus*, give rise to different rates of rheumatic fever. Of the other epidemics—type (b), however, the explanation is a little more apparent, for, if an epidemic of *Streptococcus hemolyticus* infection occurs in a population composed of individuals who are highly susceptible to rheumatic fever (such as a group of those who have previously had the disease) then we may expect a high rate of "rheumatic complications" to occur. This may happen in hospital wards or convalescent homes or camps, and herein lies the explanation for some of the concentrated groups of cases which have been reported as epidemics of rheumatic fever.

CONCLUSION

Rheumatic fever is a common and serious infectious disease in which neither the pathogenesis nor the complete clinical picture has been established. It is a disease that is often associated with or follows close upon the heels of a *Streptococcus hemolyticus* infection. It is commoner in temperate than in tropical or subtropical climates. It finds its highest incidence among the poorer classes of urban and industrial populations

It has a familial prevalence closely resembling that of tuberculosis and children of rheumatic parents seem to be more apt to acquire the disease than do those of nonrheumatic parents Its period of greatest susceptibility seems to lie between the ages of 5 and 15 Under certain conditions epidemics of the disease may appear in families and in institutions

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CHAPTER V

RHEUMATIC FEVER: EVALUATION OF ACTIVE INFECTION

By T. Duckett Jones, M.D.

Introduction: The greatest difficulties relative to the evaluation of rheumatic fever do not occur when the patient is acutely ill. True there are many diagnostic problems among patients having abundant evidence of severe illness. Some of these decisions are difficult clinical problems. For instance, it may be all but impossible at times to determine whether a patient has rheumatic fever or the acute onset of rheumatoid arthritis, or of Still's Disease in children. An interval of months or even several years may be required for this differentiation. Recently, lupus erythematosus disseminatus seems to present a more common diagnostic problem. In a patient with previous rheumatic fever or rheumatic heart disease, it may be difficult to determine whether the patient has rheumatic fever or subacute bacterial endocarditis. In this same group of patients, the question often arises as to whether active rheumatic fever may be playing any rôle coincidentally with other disease processes.

Impossible to answer as some of the above questions are, the commoner and perhaps the more important problem, relative to a patient with previous rheumatic fever, is the determination of whether rheumatic fever is in an active stage or not. This evaluation or determination of the activity of the disease process must be kept continually in mind, and is of primary importance to the patient since there is good evidence suggesting that it is during active rheumatic fever that heart disease develops or increases. Fatalities, certainly in the first two or three decades of the disease, occur coincidental with certain clinical findings and pathological changes representing the syndrome which we call rheumatic fever. Hence, the therapy in rheumatic fever and the immediate disposition or care of

such patients is largely dependent upon this evaluation of active rheumatic fever.

Certain inherent difficulties present themselves. A diagnosis of rheumatic fever is dependent upon a previous or present clinical syndrome or the development of the rheumatic type of heart disease. No specific diagnostic tests exist, and to actually define the disease syndrome is difficult if not impossible at the present time. Further, the helpful laboratory tests are distinctly nonspecific and are abnormal in many diseases other than rheumatic fever. Hence they must be considered as helpful only in the presence of other evidence of rheumatic fever, past or present, and one must be careful that no other disease or condition exists simultaneously which may be responsible for the abnormality.

A striking advance in our knowledge of rheumatic fever has come with the realization that the disease is not one of the heart and joints alone. Extensive changes may be found in varied tissues. The generalized distribution of the pathological lesions have been reviewed by Sacks[59] and Swift.[67] They have been more fully described by Klotz,[32] Pappenheimer and von Glahn,[46, 47] by Paul[48] and others. The clinical description of the more acute phases of rheumatic fever was admirably presented as early as 1889 by Cheadle.[10] More recently Swift[67] described the clinical syndrome and divided the usual manifestations into three types, *i.e.*, (1) monocyclic, (2) polycyclic and (3) continuous. Perhaps too much attention has been directed to the distinction between the juvenile and adult forms of rheumatic fever. While it is undoubtedly true that the short monocyclic form of rheumatic fever does occur more often in adults, the more chronic or continuous form may be observed frequently in older patients as well as in children. It may be safely said that in any age group the more closely patients with rheumatic fever are studied, the more conscious one becomes of the chronicity of the disease.

Rheumatic fever is a repetitive disease. It is not always clear as to just when the disease begins. Hence it is difficult to determine whether one is dealing with the first attack or a recurrence or recrudescence of the disease. We do know, however, that recurrences of rheumatic fever are very common during the first few years from the onset of the initial clinical recognition of the disease. For five or six years from the onset, it is common to have the disease recur, and most students of the disease are impressed with the close association between these manifestations of acute

disease and infection of the upper respiratory tract Such infections of the respiratory tract (tonsillitis, pharyngitis, coryza, etc) are commonly associated with hemolytic streptococcus infection, either primary or secondary

Coburn[11] and Coburn and Pauli[12 13 14] have presented much data, clinical and immunological, concerning the importance of some types of hemolytic streptococci in the initiation of rheumatic fever Wilson and her co workers[73 74 75] have not been impressed with this correlation, or relationship and are more inclined to consider the relationship as being *comparable to the deleterious effect of respiratory infection on* patients with tuberculosis Jones and Mote[29] have reported a clinical and immunological study which stresses the seeming importance of *hemolytic streptococcus infection in patients with rheumatic fever, but* they have felt that information at present available does not necessarily indicate that such infections are the cause of rheumatic fever, despite the seemingly close clinical association The present report is, however, not a discussion of the etiology of rheumatic fever, but one concerned with the evaluation of the active disease process Other considerations relative to the natural history are of importance here

Bland and Jones[5] have noted that various events are seemingly associated with or apparently precipitate recurrences of rheumatic fever Respiratory infections are by far the commoner event, but others must be kept in mind Operative procedures of various types (tonsillectomy, laparotomy, tooth extraction, and others), injuries and accidents, and nonstreptococcal infections have been observed in as close association with recurrences of rheumatic fever as respiratory infection It is possible that emotional crises may be of some importance, especially in chorea These authors observed the development of recurrent rheumatic fever following the use of single small intravenous doses of typhoid paratyphoid vaccine when used as nonspecific shock therapy Especially is rheumatic fever likely to become more severe and even fulminant following respiratory infection or the other events noted above, if any degree of active rheumatic fever was present at the time of the event

The interval between these events and the evaluation of active rheumatic fever must be kept in mind At times symptoms of rheumatic fever occur almost immediately, while often there may be a latent period of 10 to 14 days and even three or four weeks Laboratory tests may be

abnormal for two or three weeks after some of these events without indicating that rheumatic fever has become active This is of practical importance in the evaluation of the active disease process

It must be remembered that in such a chronic disease *often characterized by repetitive acute illness* there must be all degrees of severity In the acute disease evidence of active rheumatic fever is obvious and *it is in the more chronic or low grade forms that difficulty is encountered* Determination of when the disease seems to become quiescent is also important Attention will be directed hence chiefly to the clinical and laboratory *findings which are most commonly useful* in evaluating chronic low grade rheumatic fever Laboratory evidence of active rheumatic fever often and usually persists long after the clinical symptoms have subsided and they are extremely important in the management of the patient A few charts from illustrative cases will be included to stress particular points

I CLINICAL EVIDENCE OF ACTIVE RHEUMATIC FEVER

1 **Fever** Many observers consider fever the most frequent evidence of active rheumatic infection It is of course usually present in severe acute illness Once the acute stage of the disease is over the temperature level is usually lower but often persistent So important is this finding that all patients suspected of active rheumatic fever should have a carefully recorded temperature chart It should also be remembered that the influence of antipyretic drugs must be considered since such drugs even in small amounts may prevent the recognition of slight rises in temperature

Persistent fever may be of several types By far the commoner form is for the rectal temperature to have frequent daily peaks between 37 8° and 38 3° C (100° and 101° F) Occasionally there may be short cyclic elevations of temperature occurring *at varying intervals and lasting* several days at each cycle (Fig 1) There is at times a suggestion of such a cyclic swing even when the height of the temperature does not exceed a high normal level In other instances the temperature may be higher and more persistent reaching a level of 38 3° to 38 9° C (101° to 102° F) or more and at times almost simulating the temperature curves seen in subacute bacterial endocarditis (Fig 2)

The recording of the temperature by rectum has proven to be of far more value than by mouth and in general this method is recommended. A rectal temperature of 37.8° C. (100° F.) is considered the upper limit of normal.

Swift[69] believes that fever is the commonest and most important factor in determining the presence of activity. The low-grade nature of the fever has been stressed by St. Lawrence,[60] McCulloch,[41] Bourne,[5] and others.

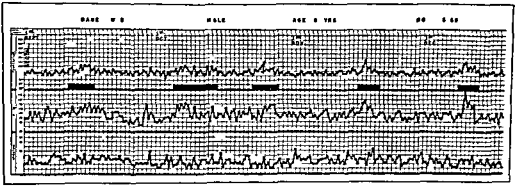

FIGURE 1. W. S., male, aged eight, H. G. S. No. 5165. Short record of a patient with protracted rheumatic fever. The black blocks indicate periods of rather cyclic increase in the severity of rheumatic fever. Other symptoms at the time of the cycles were precordial pain and transient mild joint pain. There was severe rheumatic heart disease and laboratory abnormalities were present during the intervals.

It is rare that fever is the only evidence of active rheumatic fever, but its presence in the absence of any cause other than rheumatic fever, should cause suspicion that the disease is active. It must be remembered that active, even severe, rheumatic fever may be present without fever.

2. Joints: For some years rheumatic fever literature has been concerned with the fact that the joints themselves represent a relatively mild and unimportant feature of the disease process. This was expressed by Garrod[22] in 1890, when he wrote: "If it be once granted that an attack of chorea with endocarditis or an eruption of a cutaneous erythema, may constitute as truly a rheumatic attack as the most severe forms of articular lesions, it is obvious that arthritis must be deposed from the position of the essential rheumatic lesion and must be looked upon merely as the most constant and conspicuous of the manifestations of the disease."

In a series of 1000 rheumatic fever and heart disease patients observed by the author, about 70 per cent gave a history of joint symptomatology at some stage of their disease. In general, severe arthralgia has not been

common, although occasionally the characteristic migratory polyarthritis with redness, heat, swelling, and pain is encountered. This is commonest in the adult patient, and is not often seen in young children. In a rheumatic fever subject, the finding of definite objective joint involvement leaves little clinical doubt as to the presence of active rheumatic fever. At times, there may be evidence of definite joint change, easily observed by examination and x-rays. In such cases, the differential diagnosis between rheumatic fever and rheumatoid arthritis is necessary. No perma-

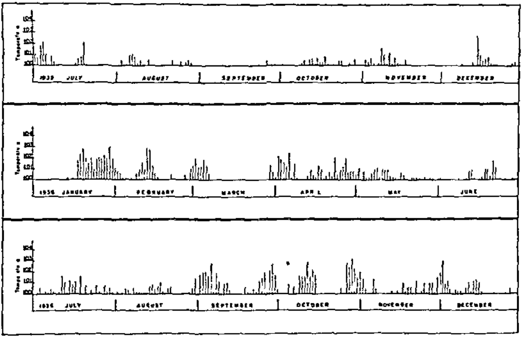

FIGURE 2 W L., male, aged ten, H G S, No 6111 Protracted fever in a patient with severe and ultimately fatal rheumatic fever The curve is somewhat cyclic Congestive heart failure was present in varying degrees during most of this 18 month period

nent joint destruction occurs in rheumatic fever and such changes in the presence of rheumatic heart disease suggest that the two diseases at times occur simultaneously. The association is not encountered often enough to be conclusive with regard to the consideration of common factors in etiology.

The importance of mild joint symptomatology cannot be overestimated, and the appearance of such symptoms as stiffness, aches, mild pain, etc., must be considered, and would seem of sufficient importance to warrant a careful search for other evidence of active rheumatic fever.

Whether their appearance alone justifies too much consideration is hard to determine but the writer is impressed with the fact that such symptoms frequently precede recurrences or that they are a part of a syndrome recognized by careful watching of temperature charts and blood counts. The importance of growing pains has likewise received widespread attention. These pains often occur behind the knees. While many individuals exhibiting only growing pains may not be expected to develop evidence of heart damage, it is a sufficiently frequent finding in the history of patients with rheumatic heart disease (and no other history of joint complaint) to justify its presence being considered as a warning signal and to warrant a definite search for other manifestations of the disease which may be easily overlooked. It would hardly seem justifiable to carry the idea of therapy to the point of bed care for every transient type of joint complaint, but such symptoms, especially in a patient stigmatized by evidence of previous rheumatic fever, may prove important and should not be disregarded.

3 **Subcutaneous Nodules** In recent years much attention has been directed toward the finding of subcutaneous nodules in rheumatic fever. The majority of individuals exhibiting this evidence of proliferative change have severe heart disease and active infection. The fact that they are likely to occur in individuals with the severe disease process has resulted in a feeling that they indicate a grave prognosis. The presence of nodules during acute illness often justifies this impression. Since a large part of the recovery process in rheumatic fever is a proliferative one, the author does not feel that there is justification for considering them as always indicative of a poor outlook. It is very striking that in *those cases having low grade active infection and the common finding* of being underweight and exhibiting nodules, improvement usually occurs with the disappearance of the nodules. The appearance of nodules seems to vary considerably in different localities. This has been stressed by variations in percentages of cases in which nodules have been found, especially in the writings of English observers. It may be justifiable to state that unless subcutaneous nodules are very large and present in goodly numbers, it is a simple matter to overlook them on examination of the patient. Failure of recognition of the presence of nodules and their evident annual variation in frequency would seem likely as a cause

of some of the discrepancies Should nodules be searched for diligently their presence may be detected in unsuspected cases

Subcutaneous nodules are usually multiple and may appear in crops over the bony prominences and sometimes on tendons They are painless nontender vary considerably in both size and consistency and may be present from a few days to several months or longer They have been considered to represent the characteristic pathology of rheumatic fever but Dawson[18] considers them to be histologically very similar to the nodules seen in rheumatoid arthritis Recently Massell Mote and Jones[38, 43] have demonstrated that nodules may be artificially induced in rheumatic fever subjects These artificial nodules seem clinically to be indistinguishable from and histologically very similar to spontaneous nodules The complete significance of this finding remains to be determined

Subcutaneous nodules are found in rare instances in the absence of other manifestations of active rheumatic fever but even here they should be considered definite evidence that the proliferative stage of rheumatic fever is in progress

4 Erythemas The association of various erythemas with rheumatic fever has long been recognized The commonest rash is some form of erythema multiforme and as a rule is erythema marginatum although erythema papulatum is not unknown The finding is sufficiently frequent in those individuals with other manifestations of the disease to warrant a careful interpretation as to the probability that the presence of erythemas indicates active infection Their frequent occurrence in cases having nodules or in whom subcutaneous nodules have recently disappeared leads to the belief that erythemas may be associated in some way with the recovery phase of the disease

The rash is often transitory in nature and may be easily overlooked There is no itching edema or hemorrhage The lesions are pale red or bluish red ringlets of various size with a pale center The rash fades as a rule in 18 to 24 hours but is likely to appear on successive days It is macular and disappears without scaling or pigmentation The lesions are most commonly found on the flexor surfaces of the arms and on the chest Rarely do they appear on the legs and never on the face or mucosae The lesions are at times symmetrical

Erythema marginatum occurs at times soon after the onset of rheumatic fever However it more commonly appears when the disease has assumed a more chronic stage In the female we have noted the frequency at which the rash may appear a day or two before or during menstruation In one patient the rash appeared at the time of each menstruation for a period of 14 or 15 years This patient had moderately severe rheumatic heart disease and there was other evidence of active rheumatic fever at the time of each examination The other manifestations were leukocytosis a rapid sedimentation rate or prolongation of the auriculoventricular conduction time by electrocardiogram At times though rare erythema marginatum may be the only clinical symptom of active rheumatic fever The following short case report illustrates the association between this rash and the other manifestations of rheumatic fever as well as its presence as the only apparent evidence of the active disease

E I H G S No 1002 female aged 16 readmitted to the House of the Good Samaritan February 8 1933 Onset of rheumatic fever in 1924 at age seven and hospitalized for one year at that time Definite cardiac enlargement and mitral disease at that time Rheumatic fever recurred in 1929 1930 and 1931 Mild aortic disease developed during this seemingly continuous period of rheumatic fever In January 1933 she developed fever and migrating polyarthritis following a sore throat After hospital admission there was continued evidence of active rheumatic fever Repetitive erythema marginatum occurred on successive days or with only a few days interval In addition there were frequent nosebleeds rare mild transient joint pains and occasional slight rises in temperature The white blood count was at no time elevated There was however a microcytic anemia a fast sedimentation rate and prolongation of the auriculoventricular conduction time by electrocardiogram Weight gain was not satisfactory During a period of 12 to 14 months the patient improved somewhat but conduction time remained prolonged and erythema marginatum occurred frequently On July 1 1934 there was a sudden rise in temperature to nearly 40.5° C (105° F) which appeared clinically to be a heat stroke Shortly after this pulmonary edema occurred and the patient died within several hours It was of real interest that for a period of three months or more prior to death erythema marginatum was the only symptom of active rheumatic fever, and the only laboratory abnormality was the prolonged conduction time by electrocardiogram Autopsy revealed extensive myocardial fibrosis and there were numerous Aschoff bodies present A good many of these Aschoff bodies were old while others were apparently of a young age

5. Precordial Pain: The presence of sharp, transient, precordial pain has been noted by numerous observers, and at times it is an early symptom of a rheumatic recrudescence. Such a symptom must be carefully evaluated, in view of the frequency of well-defined effort syndrome in patients with rheumatic heart disease. In children, precordial pain is more significant than in adults, and less often is there confusion concerning its interpretation The transient heart consciousness accompanying extra systoles and found frequently in nervous individuals should not be confused with significant precordial pain.

Severe, prolonged pain, suggestive of that found in coronary disease, may be observed in rheumatic fever and rheumatic heart disease subjects, though mercifully it is an unusual occurrence. It may be so severe as to necessitate rather drastic measures for relief. The report of Bland and White[6] of the relief of such pain by the paravertebral injection of alcohol is interesting. Such severe pain as that described by these authors is of serious prognostic import. The changes found in coronary vessels in rheumatic fever and reported by various observers (Karsner and Bayless,[31] Gross, Kugel and Epstein,[25] and others) offer an explanatory anatomical basis for the pain. The mechanism of such severe precordial pain is doubtless different from the cause of anginoid pain seen in older rheumatic heart disease subjects with free aortic regurgitation.

Perhaps the most common cause of significant precordial pain in rheumatic fever is due to pericarditis. At times, pleuritis may be a factor. Friction rubs are often heard, and, as a rule, the patient is obviously ill with rheumatic fever The frequency with which pericarditis and pleuritis are found post mortem in rheumatic fever subjects indicates that such a basis for pain must be very frequent in the course of the disease.

6. Chorea: The association between Sydenham's chorea and rheumatic fever is a time-honored one. With the omission of habit spasm and purposeless movements of evident neurogenic origin, it has been considered safe to consider choreiform movement as a part of the rheumatic fever syndrome. Coombs,[17] Poynton and Schlesinger,[51] Findlay,[20] and others have expressed this opinion. The dicta of Osler[45] concerning the importance of chorea in the development of rheumatic heart disease is well known. In more recent years, Swift[68] has stated that "chorea is one of the grave manifestations in childhood."

Gerstley, Wile, Falstein, and Gayle[23] have concluded that chorea is not a disease, but a symptom, more frequently of psychic trauma than of rheumatism. It is, of course, evident that all purposeless movements are not true Sydenham's chorea, and that some diversity of opinion exists. In some instances it is difficult to make a definite diagnosis. Since the etiology of rheumatic fever remains unknown, it is not surprising that much confusion exists with regard to the relationship between it and chorea. Further, there is no absolutely certain diagnostic test available, and the diagnosis of rheumatic fever is often difficult. Hence, reliance must be placed upon the close clinical association between rheumatic fever and chorea in determining a relationship.

Ash and Einhorn[1] have recently stated that the association is so close that it is safer to consider any child with chorea as potentially a patient with rheumatic infection. In this respect it may be well to quote the series of Jones and Bland,[28] who analyzed chorea as a single manifestation of rheumatic fever in an effort to evaluate its significance as a part of the rheumatic fever syndrome. A group of 1000 rheumatic fever and chorea patients were observed over an average period of eight years. Of these patients, 482 at some time had chorea; 28 per cent had chorea alone, and 72 per cent also had other symptoms of rheumatic fever. Of 134 patients having no other manifestation of rheumatic fever, the incidence of rheumatic heart disease was only three per cent. Of 184 patients who exhibited other evidence of rheumatic fever subsequent to chorea, rheumatic heart disease was found in 80 per cent. Of 164 subjects who had chorea subsequent to rheumatic fever, rheumatic heart disease was found in 66 per cent The number of attacks of chorea did not appear to influence significantly the development of rheumatic heart disease. The above data, together with the low mortality rate in uncomplicated chorea, and the rarity of severe manifestations of rheumatic fever in chorea patients, led these authors to conclude that "chorea is considered to be a mild manifestation of rheumatic fever and one in itself not especially conducive to the development of rheumatic heart disease" Sutton and Dodge[66] have recently agreed in general with the above findings.

The work of Jones and Bland[28] does not warrant the separation of true Sydenham's chorea from a close relationship with rheumatic fever. It does, however, indicate that chorea is one of the less significant and better prognostic findings in the course of rheumatic fever. Choreiform

movement in the absence of other clinical or laboratory manifestations of rheumatic fever should not cause great alarm unless the choreiform movement is violent and exhaustive

7 **Pulse Rate** The evaluation of the pulse rate in the determination of the presence of an active disease process is often difficult Whenever fever is present elevation of the pulse rate usually parallels the fever as in other infectious disease The persistence of a rapid pulse in child or adult should be considered suspicious and investigated There are so many factors controlling the pulse rate that some skepticism should be entertained with regard to the interpretation of a rapid pulse in the absence of other evidence of active rheumatic fever The sleeping pulse rate has recently received attention and would seem to be more valuable than the rate when awake Struthers and Bacal[64] and more recently Rosenblum[54] have noted this A quickening of both sleeping and alert (awake) rates would be consistent with active rheumatic fever while a drop of 10 to 20 beats per minute during sleep probably indicates that the rapid alert rate is of nervous origin

Persistent significant tachycardia may be encountered but rarely as the most striking feature of the patient s illness It is probable that other manifestations of active rheumatic fever are more important than the pulse rate This does not of course include various arrhythmias which of themselves are definitely important not necessarily as evidence of infection but as a frequent concomitant of rheumatic heart disease

8 *Epistaxis That frequent nosebleeds seem to have a definite* association with rheumatic fever especially relatively low grade processes has been stressed by Libman[36] and by Levine Andren and Homans[34] *While the presence of nontraumatic epistaxis alone would hardly be con*sidered as a very important manifestation of rheumatic fever it has been pointed out by Coburn[11] in a large series of cases that it has preceded a *recrudescence more frequently* than has any other symptom and has been a common accompaniment of the active rheumatic process This would seem in keeping with the opinion of many men who are observing large numbers of rheumatic fever patients While epistaxis itself does not render a definite diagnosis of rheumatic fever possible it must nevertheless be seriously considered as evidence of activity in a patient with definite rheumatic heart disease or a history of previous rheumatic fever

siderably underweight patients with rheumatic fever subsequently develop nodules and erythemas is striking (Fig 3) In this type of case an appreciable gain in weight may not occur until the disease process subsides, which is often coincident with disappearance of nodules and

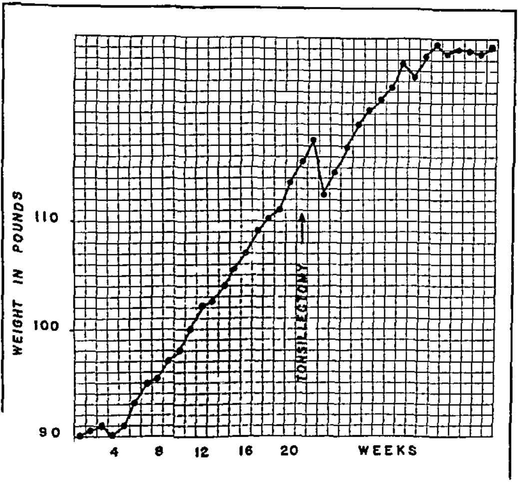

FIGURE 4 R T female aged 15 H G S No 5378 First rheumatic fever at age ven Third severe recurrence of rheumatic fever began eight months prior to the eekly weight chart above The rapid weight gain closely paralleled the subsidence f clinical and laboratory evidences of active rheumatic fever Rheumatic fever con . to be inactive just prior to tonsillectomy Note the post tonsillectomy weight loss which is customary in this group of patients

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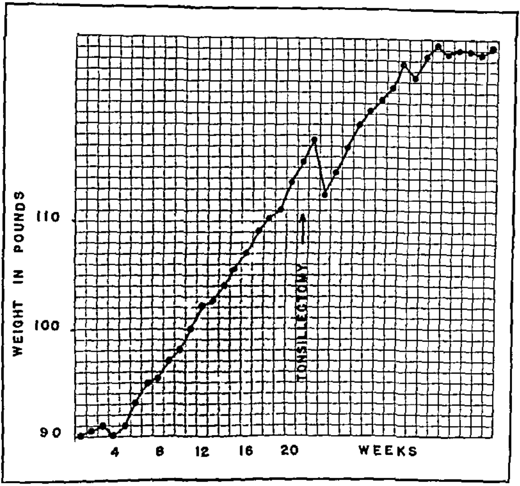

FIGURE 4 R T female aged 15 H G S No 5378 First rheumatic fever at age seven Third severe recurrence of rheumatic fever began eight months prior to the weekly weight chart above The rapid weight gain closely paralleled the subsidence of clinical and laboratory evidences of active rheumatic fever Rheumatic fever considered to be inactive just prior to tonsillectomy *Note the post tonsillectomy weight* loss which is customary in this group of patients

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siderably underweight patients with rheumatic fever subsequently develop nodules and erythemas is striking (Fig 3) In this type of case an appreciable gain in weight may not occur until the disease process subsides which is often coincident with disappearance of nodules and

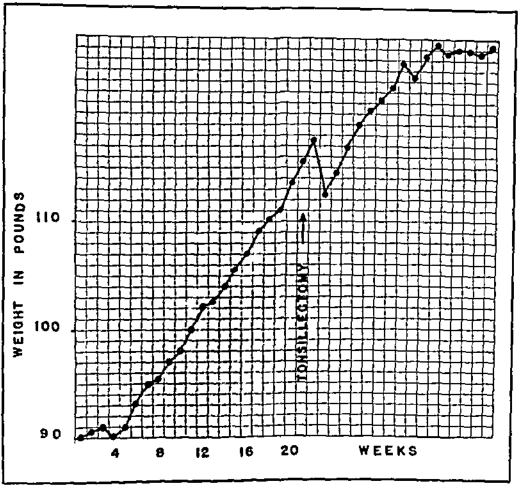

Figure 4 R T female aged 15 H G S No 5378 First rheumatic fever at age seven Third severe recurrence of rheumatic fever began eight months prior to the weekly weight chart above The rapid weight gain closely paralleled the subsidence of clinical and laboratory evidences of active rheumatic fever Rheumatic fever considered to be inactive just prior to tonsillectomy Note the post tonsillectomy weight loss which is customary in this group of patients

erythemas The importance of weight as a guide to recovery is apparent after observing a few cases of this type In patients receiving long bed care, failure to gain weight is usually found to be dependent upon the presence of active disease It is generally found that slow, gradual increase in weight is consistent with other evidence of diminution of activity of

the disease process (Fig 4) In an individual who is definitely over weight only meager information can be obtained concerning the disease process and habitual weight and constitutional factors must be considered

10 **Pneumonitis** Changes in pulmonary vessels have been described frequently and their presence is one reason for believing the disease to be a generalized one In addition to this there may be recognized during life certain lung changes occurring during active infection and without congestive heart failure Naish[44] has considered these changes in the parenchyma of the lung as being of a specific rheumatic character although this has not been accepted by all observers Clinically pneumonitis may occur as has been pointed out by Rabinowitz [52] Boas and Schwartz [7] Paul [48] Swift [67] and Coburn [11] As a rule this would seem to be a quickly varying or migratory process of short duration and it may occur even without symptomatology It has never been recognized by the author except in severe illness and its presence in the literature has been noted usually in those individuals who are acutely ill and with other manifestations of rheumatic fever The hemorrhagic nature of the process has been generally agreed upon in pathological studies

11 **Abdominal Pain** The cause of abdominal pain in rheumatic fever cannot as yet be definitely determined It is of frequent occurrence and next to epistaxis was found by Coburn[11] to be the most frequent presenting symptom of the disease complex In a number of cases the diagnosis of appendicitis has been made and a normal appendix removed in a few of them only to be followed in a short period by other manifestations of rheumatic fever In an individual with definite stigmata or a history of previous rheumatic fever it would be wise to rule out the association of the pain as a part of rheumatic fever It would not be desirable to infer that patients who have rheumatic fever may not have other causes of abdominal pain and the usual causes of abdominal pain should not be overlooked in a decision as to the cause of the difficulty

12 **Exercise Tolerance** Easy fatigability and weakness are common complaints of individuals with heart disease of any type Their presence in individuals with rheumatic heart disease is frequent They may occur as symptoms early in an active disease process but their interpretation is difficult and there would be hesitation in considering these symptoms

alone as sufficient evidence of active disease Definite decrease in pulmonary ventilation as measured by means of a spirometer has been reported by Wilson[72] When there is a reliable and repeated measurement of vital capacity, and this has been checked with exercise tests, Wilson feels that even a slight decrease is important and indicative of active rheumatic fever or the beginning of a process often resulting in cardiac failure The author has had no experience with this test

Definite decrease in exercise tolerance in young patients with rheumatic heart disease is found during rheumatic fever and is often a precursor of serious congestive failure

13 **Congestive Failure** The presence of congestive failure in a young patient with rheumatic heart disease is in itself definite evidence of active rheumatic fever It is difficult to determine the exact age limit in this regard Rothschild Kugel and Gross[55] have presented pathological evidence of the importance of active rheumatic fever rather than mechanical defects in precipitating fatal issues These observers feel that patients with rheumatic heart disease dying before 40 years of age or perhaps older, die of the underlying rheumatic infection In the author s experience, this would certainly be true of those patients dying under 30 years of age It is likely that exhaustive search of post mortem material from older rheumatic heart disease patients would often present evidence of *active rheumatic fever* as well as the extensive old lesions The majority of the fatalities in the young subjects occur within five or six years from *the onset* of the disease and by adolescence In this group active rheumatic fever is unquestionably present

Hence, congestive failure is not only a serious prognostic factor but may be regarded as evidence of active rheumatic fever This is found to be *true regardless of a normal temperature, white blood count or sedimentation rate* of red blood cells

14 **Other Manifestations** *Numerous other signs and symptoms* have been suggested as being part of the syndrome of rheumatic fever Of these, vomiting *pallor, headache, urticaria, iritis, and torticollis may* be mentioned While their presence may be suggestive it is hardly possible to consider these as being *sufficient to indicate active infection,* when no other manifestations are present or develop Changes in the heart upon physical *examination as to size, murmurs, etc , are interesting* findings and, while they may indicate an increase in clinically detectable

heart damage their presence alone cannot be considered as denoting active disease These findings and changes are the result of the active infection rather than in themselves a manifestation

II LABORATORY EVIDENCE OF ACTIVE RHEUMATIC FEVER

1 **Blood Changes** For many years it has been recognized that there is definite leukocytosis almost invariably accompanying rheumatic fever its importance has been stressed and some have considered it as the most accurate criteria for the determination of the duration of the active disease process It is undoubtedly of considerable importance but many factors must be controlled and considered Some of the difficulties and variations in the white blood count have been noted by Garrey and Bryan [31] Ponder Saslow and Schweizer [50] Medlar [42] Sabin Cunningham Doan and Kindwall [58] Smith and McDowell [60] and Shaw [61] It has been found in rheumatic fever patients just as in normal subjects that the highest peak of the diurnal variation in white blood cells is between noon and 3 00 P M These variations at different hours of the day may be as great as 100 per cent and whether they are greater than those seen in normal individuals is as yet unknown nor has it as yet been determined whether they are due to a redistribution of white blood cells or to an increased output of cells from the blood forming organs Counts should be made frequently and performed at a definite fixed time in subsequent examinations This would tend to do away with an otherwise considerable error in interpretation of results

It has been shown by Swift Miller and Boots [70] that elevation of the white blood count is usually found just prior to a definite recrudescence A white blood count above 9000 or 10 000 is considered evidence of active disease unless its cause is associated with some other type of infection There is a strong tendency on the part of at least the juvenile forms of rheumatic fever to show a persistently elevated white count usually coincident with mild occasional elevation of temperature for a considerable period of time and the frequency of this combination leads to the belief that they are important as a guide to therapy

It has been known for some years that in blood prevented from coagulating the red blood cells form a sediment more rapidly under certain pathological conditions than is the case in healthy persons This property of the blood has been studied in numerous conditions such as acute and

chronic infections *inflammatory processes of various types malignant* tumors etc It presents no specific diagnostic information but may be a definite guide in determining the presence of a disease process or its disappearance It has been shown especially in Germany and Scandinavia that the sedimentation rate is increased definitely in rheumatic fever and the result of frequent estimations of *this reaction is used as a guide to* treatment in some foreign hospitals

The majority of workers familiar with the sedimentation rate in rheumatic fever has been distinctly impressed with the value and significance of the test Among these may be listed Westergren[71] Kahlmeter[30] Herrmann[26] Ernstene[19] Bach[2] Bach and Hill[3] Payne and Schlesinger[49] Struthers and Bacal[64] Rogatz[53] Coburn and Kapp[15] and others The test is of distinct value but one must be certain that an increase in the sedimentation rate is not caused by factors other than rheumatic infection In the author s experience the most reliable method is that of Rourke and Ernstene[57] With this method the hematocrit is determined and a correction made for anemia This has proved to be of distinct value in rheumatic fever Recently Massell and Jones[3] have compared the relative value of the sedimentation rate and leukocyte count in evaluating the presence of active rheumatic fever White blood counts were performed at frequent intervals and sedimentation rates determined by the method of Rourke and Ernstene[57] In about one half of the patients followed the leukocyte count returned to normal first while in the remainder *the sedimentation rate was the first test to reach a normal* level *In view of the technical error in performing leukocyte counts and the tremendous daily variations the sedimentation rate is considered to be the more reliable test if only one is to be performed* However abnormalities of either test are considered to indicate active rheumatic fever and may be found to remain abnormal for many months They are valuable guides to therapy Following a respiratory infection the sedimentation rate may remain elevated for two to three weeks In a rheumatic subject such an interval should elapse prior to using this test in evaluating the activity of the rheumatic fever process

Rogatz[53] and Struthers and Bacal[64] have considered the sedimentation rate of more value in regard to the activity of rheumatic fever than the Schilling count

Quite similar to the increased sedimentation rate of red blood cells is *the increase in the fibrin content of the blood.* This determination also gives no specific information, but is a general reaction in certain disease states. Bezançon and Weil[4] consider it of definite value in the study of the progress of the disease process in rheumatic fever.

A definite increase in immature forms in the myelocytic series is found early in the course of acute rheumatic fever. This increase, as determined by the Schilling count, may even precede clinical evidence of recurrent rheumatic fever. It does not, however, persist so long as the increase in *the sedimentation rate, and hence is not so valuable in determining the presence of active rheumatic fever.*

Mild to moderate anemia does occur in rheumatic fever. Hubbard and McKee[27] reported such a study. Early in the disease there is a fall *in the red blood count and a rather disproportionate drop in hemoglobin.* The hematocrit also falls. All of these features may remain persistent for long periods, returning to normal with the cessation of active rheumatic fever. This is especially true in the child with severe chronic rheumatic fever.

In addition, the occasional occurrence in rheumatic fever cases of petechiae and purpura, without the usual alterations in the blood found in purpuric conditions, must not be overlooked. Petechiae are most apt *to occur along sites subject to trauma* Other evidences of rheumatic fever are usually present. While neither of these is a common finding, they would seem to indicate definite weakness of the minute peripheral vessels, which is not unexpected in rheumatic fever, and which probably indicates that the disease is active.

2. Electrocardiographic Changes: Numerous observers have recorded the importance of electrocardiographic changes as a manifestation of active infection in rheumatic fever. Cohn and Swift[10] have reported changes in a very high percentage of acutely ill patients. In addition, the work of Rothschild, Sacks and Libman,[56] and of Levy and Turner[35] is well known. The usual change considered by the majority of investigators as indicative of active difficulty is prolongation of the auriculoventricular conduction time. The usual finding is simply prolonged conduction time (above 0.2 second), although there are reports in the literature of even complete auriculoventricular block. It is thoroughly possible that in children a P-R interval of 0.18 second or less

should be considered significant In addition to this reports concerning changes in the Q R S complexes variation in interval between the R and T waves and changes (usually inversion) in the T wave itself have been noted These changes have recently been pointed out by Master and Jaffe[39] The cause of these changes is argumentative Suffice it to say that as a guide in determination of the presence of active infection frequent electrocardiograms are of definite value and the occasional finding of a temporary prolongation of the auriculoventricular conduction time as the only evidence of active infection would warrant the justification for this procedure While prolongation of conduction time is often a transient phenomenon it has been found at times to be present for several months or one to two years although permanent changes in the conduction time as a result of rheumatic fever have not been recognized by the author

The interpretation of this prolongation of the auriculoventricular conduction time is difficult If the result of actual changes in the heart it would be one of the most positive indications of active carditis Bruenn[9] and Keith[32] have recently discussed the mechanism of such conduction defects and indicate that they may be dependent upon supracardiac influences The probability of over stimulation of the vagus nerve as the likely mechanism of this abnormality does not alter the clinical importance of the finding in patients with rheumatic fever or rheumatic heart disease

3 **Urinary Changes** The occasional presence of urinary findings indicative of acute nephritis is well known during the acute illness of rheumatic fever The finding of hematuria is also occasionally associated with the acute illness Coburn[11] in his excellent monograph seems to lay great stress upon the picture of acute nephritis in the disease as well as the occurrence of hematuria and seems to deem it sufficiently important to place hematuria as one of the classical signs of active rheumatic infection While those individuals with mild low-grade active infection do not often show a diminution in kidney function microscopic red blood cells are nevertheless found if frequent urinary examinations are made This would appear comparable to the finding of petechiae and nosebleeds during the active disease process Swift[illegible] has pointed out the frequency of the relationship between the onset of hematuria cylindruria and

polyarthritis being close enough to make the physician feel that there is a common cause

Stettner[63] describes what he is pleased to call heightened capillary vulnerability in 33 of 50 rheumatic children manifest by persistent microscopic hematuria Veil[76] has stressed the fact that an attack of nephritis is frequently the equivalent to a bout of polyarthritis during the course of rheumatic fever The large volume of literature concerning the association between nephritis and streptococcal infection would also indicate that there could very likely be a relationship between nephritis and rheumatic fever

The report by Goldring and Wyckoff[24] giving kidney studies of 16 patients with rheumatic fever is highly suggestive of the frequency of mild kidney changes during acute rheumatic fever An increase in the excretion of protein and formed elements (Addis sediment count) was found persisting for four to ten weeks after the subsidence of the acute symptoms These observers suggest that their findings are consistent with a diagnosis of focal glomerulonephritis

While evident kidney changes during acute illness may be interpreted as a part of the disease syndrome the insignificant findings later in the disease have not been considered of sufficient import Persistent or frequent abnormalities (such as microscopic hematuria) in an individual with rheumatic heart disease or with a history of previous rheumatic fever are worthy of being classified as a manifestation of the active disease state

SUBCLINICAL RECURRENCES OF RHEUMATIC FEVER

As pointed out in the introduction recurrences of rheumatic fever may be of any degree of severity One important reason for evaluating the presence or absence of active infection during periods of apparent quiescence is that active rheumatic fever may be asymptomatic and heart disease may result during periods when laboratory tests alone indicate active infection Especially should the patient be carefully observed for a few weeks following events previously noted as being commonly associated with the onset of recurrences of rheumatic fever Figures 5 and 6 are examples of such clinical recurrences No clinical symptoms of rheumatic fever occurred but abnormal laboratory findings were observed and

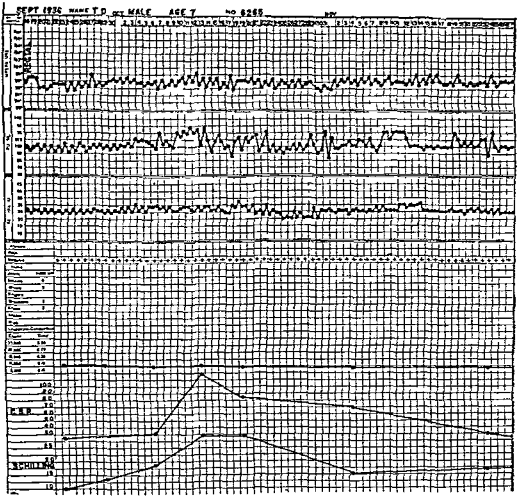

FIGURE 5 T D male aged seven H G S No 6265 First rheumatic fever two and one-half years prior to clinical chart above Recurrent rheumatic fever six months prior to chart and had congestive failure at onset for a few weeks No clinical respiratory infection during the interval noted Note the abnormal corrected sedimentation rate (0.38 mm per minute normal) for five to six weeks There was also a swing to the left of the Schilling index No alteration of the white blood count and no change in the clinical symptoms Considered to represent a subclinical increase in the severity of rheumatic fever

remained abnormal for a period longer than that usually observed as a result of colds, sore throats, or operative procedures Such episodes are doubtless common in the course of rheumatic fever, and must be constantly kept in mind in observing the progress of the disease

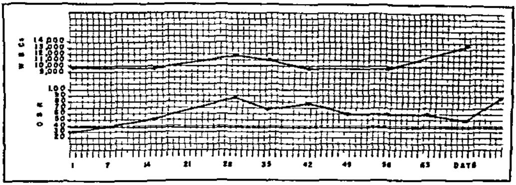

FIGURE 6 G P male aged 5 H G S No 6356 Onset of first rheumatic fever eight months prior to above laboratory data Slight cardiac enlargement and mitral disease Rheumatic fever considered inactive for past two to three months No clinical evidence of respiratory infection but hemolytic streptococci appeared in throat culture for first time just prior to first abnormal corrected sedimentation rate This was coincidental with a respiratory infection epidemic on the ward. No clinical symptoms developed *No fever* *Considered to be a subclinical recurrence of rheumatic fever* Note the rather cyclic nature of the corrected sedimentation rate

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CHAPTER VI

BACTERIAL ENDOCARDITIS

By WILLIAM DOCK, M D

Of the patients who grow up with congenital heart defects, or with valves scarred by rheumatic fever, nearly one out of four will die of bacterial endocarditis. Under this term are included a variety of clinical manifestations and nearly a score of etiological entities which have as a common feature thrombotic vegetations and ulcerations of the endocardium and valves of the heart. In addition to the various clinical types there are many lesions demonstrable at autopsy which were of no clinical importance, for the bacterial invasion of the heart was merely a terminal event, either an acute endocarditis complicating overwhelming sepsis and pyemia, or a subacute lesion developing in the final phase of a wasting disease such as cancer, uremia or tuberculosis. Cases in which the endocardial lesions determine the clinical manifestations are grouped into acute or subacute forms, the former causing a severe febrile illness measured only in days or a few weeks, the latter smouldering on for months and perhaps afebrile for much of the time. These subdivisions are arbitrary and the course of subacute cases is often cut short by embolic accidents.

Historical Note: *The history of endocardial vegetations goes back* to the days of the early anatomists, when even post mortem clots were thought of as interesting polyps. The relation of rheumatic fever to endocardial damage was clear to English and French clinician dissectors by the dawn of the nineteenth century, and bacterial endocarditis was recognized in the first years of the era of bacteriology. By 1900 all of the commoner forms and their complications were well known to pathologists and internists, although, as with infarct of the myocardium, the diagnosis was not often made in clinical circles, especially in the milder and subacute forms. Schottmuller and Libman were largely responsible for

emphasizing and making clear the nature of subacute bacterial endo carditis and Lohlein and Baehr for recognizing the high incidence and specific character of the accompanying glomerular nephritis Libman also has brought to light cases of febrile subacute endocarditis which are bacteria free throughout their course While the study of therapy has been continually and energetically pursued both in the clinic and in the *experimental animal it has not yet produced a satisfactory* management for a disease which now is correctly recognized in more than 85 per cent of our hospital cases by the student clinical clerk who first takes the his tory and examines the patient

ETIOLOGY

About 20 varieties of microbes have been isolated from lesions of the endocardium Streptococci of many types predominate other cocci of all sorts are not infrequent while the bacilli range from tubercle and influenza to diphtheroids virulent diphtheria organisms the etiologic agents of typhoid and undulant fevers of Friedlander pneumonia and the *Bacillus pyocyaneous* With most of the latter types of organisms implantation on the heart valves or the endocardium of the walls is merely an unusual complication of the illness usually caused by the specific bacterium A case of pneumonia is complicated by or followed by pneumococcus endocarditis or a gonorrheal urethritis is followed by gonococcal lesions on the heart valves and the new disease thus estab lished overshadows that from which it developed In a few cases due to nearly all these organisms and in most of those due to the nonhemolytic streptococci no febrile illness precedes the manifestations of bacterial endocarditis which seems to strike out of the blue

The infections with gonococcus and meningococcus rarely run a slow subacute course those due to nonhemolytic streptococci and the influenza bacillus only occasionally are acute but it is incorrect to consider subacute or slow endocarditis as synonymous with streptococcus viridans endocardi tis The sharp lines drawn on the basis of etiology cut across the vague and arbitrary borders of acute or subacute types of disease Various types of the streptococcus viridans (that is aerobic streptococci which cause minimal hemolysis but some change in color of hemoglobin alpha type streptococcus) dominate the bacteriology of this disease because they occur in about two thirds of the clinical cases and because they are present

in most cases in every blood culture taken over many months Per week of clinical endocarditis the nonhemolytic streptococcus is probably ten times as frequent as any other organism or even all others together Occasionally nonhemolytic (gamma type) streptococci which cause no discoloration of hemoglobin and may be anaerobes are the infecting agent These are considered as enterogenous infections since these organisms are normally present in the bowel

Acute lesions due to the pyogenic cocci kill less than three per cent of patients whose hearts or great vessels are the seat of congenital or rheumatic disease *On the other hand such lesions cause the dominant clinical* features of the final illness of 0 2 to 0 4 per cent of patients coming to autopsy without congenital or rheumatic heart disease and in such cases the right side of the heart is not infrequently involved Thus acute bacterial endocarditis is clinically most often seen in patients who have had no previous heart disease it is favored by fibrotic lesions but virulent organisms are by no means dependent on such chronic disorders for the opportunity to invade the heart

Quite different is the situation with regard to the subacute cases most of which involve the left side of the heart and are due to nonhemolytic streptococci About one third of the cases of congenital heart disease surviving into childhood [1] and one fifth of the cases of chronic rheumatic *valvular disease die of this complication but in patients without chronic* or congenital lesions subacute endocarditis due to mild streptococci is less frequent than acute endocarditis Chronic lesions on which the subacute bacterial disease is engrafted are grossly demonstrable in four out of five cases and careful histologic study proves that fused aortic cusps or *unimposing rheumatic scars are present in most of the others Thus in* subacute lesions the soil is the most important consideration etiologically and the organisms which flourish in this altered tissue are the streptococci which are commonly present in the mouth and gut They probably enter the blood stream of normal people in showers associated with such frequent incidents as *colds acute gastroenteritis tooth extractions* tonsillectomies [2] pelvic infections in both sexes and even with no clinical symptoms of any sort In acute endocarditis the virulence of the organisms and the effects of their toxins in injuring the endocardium are more important than the soil which may or may not have been prepared by previous disease

While infected emboli lodging in the vessels which are present in scarred valves or beneath the endocardium are a potential cause for these lesions it seems certain that the valvular lesions at least are due to lodgement of bacteria in the minute platelet thrombi which occur along the *lines of closure of the valves* or at places where defects cause unusual stream or soft tissue friction Such bland thrombi are most frequently found on valves altered by sclerotic or fibrotic lesions and where there are such congenital defects as fused aortic cusps patent interventricular septa or a ductus arteriosus Similar vegetations may occur in arteriovenous fistulae These bland thrombi are more likely to form when the endocardium is injured by nutritional defects toxemia or wasting disease Such thrombi are usually only of microscopic dimensions but they may form fine vegetations and such small sterile warty lesions are far more common in wasting diseases than terminal subacute bacterial endocarditis The sites where these sterile and minute thrombi form are also the favored sites for bacterial endocarditis

Once the latter disease is established the blood stream constantly contains organisms and small thrombi and if valves were normally vascularized intravalvular emboli would soon set up progressive lesions of all four valves *As a matter of fact the disease is usually found on all* scarred valves in the old rheumatic cases and only on one if the others are free of fibrotic change Kissing lesions at points where two leaflets touch and spread along lines of closure are common findings but evidence for embolic invasion of valves is absent even when embolic lesions are numerous in skin viscera the brain and as mycotic aneurysms in the walls of arteries While the lesions are occasionally confined to the walls of the heart (parietal as contrasted with valvular endocarditis) it is remarkable that the large mural thrombi which follow myocardial infarcts rarely become infected Cases in which syphilitic lesions have prepared the soil for bacterial endocarditis are also uncommon [5] In elderly patients ulcerated sclerotic lesions occasionally become the seat of bacterial endocarditis but many of the cases are not clinically significant being terminal infections of patients severely ill from other causes

In dogs it is easy to set up bacterial endocarditis on valves which have been cut or scratched [4] the disease then may develop spontaneously and can be produced not only by parenteral injection of streptococci but even by massive feeding of cultures The organisms given can be identi

fied with those cultivated from the experimentally produced lesions. It is, therefore, rather remarkable that in acute rheumatic carditis, with fine bland thrombi on the valves, bacterial endocarditis developes so rarely.[6] The soil appears to be ideal, but the immunological situation may be the important inhibiting influence. For with active rheumatic states the patient's sensitivity to streptococci is evidenced by the skin reactions which these organisms evoke. The patient with bacterial endocarditis of the common type has negative skin tests, and there is some evidence that desensitization precedes infection.[7] With sensitivity to the organisms the rheumatic patient may also have increased resistance to blood stream invasion or to successful colonization of the heart lesions.

PATHOLOGY

In the heart bacterial endocarditis causes ulceration, which is most striking in the acute cases, and the formation of thrombotic vegetations. When the infection is of low virulence the vegetations may be relatively small, firm and organized into fibrous tissue except at the outer surface. With staphylococcus infections, and less strikingly with other virulent organisms, the vegetations may be bulky and friable, composed of red cells, leukocytes, thrombocytes and coagulated protein, and contain masses of bacteria. The ulcerations may cause rupture of leaflets and tendinous cords, thus disrupting cardiac function and precipitating congestive failure. Penetrating ulcers may connect the heart chambers, or permit the infection to extend to the pericardium, causing diffuse fibrinous pericarditis. The vegetations are the source for emboli which manifest themselves in the skin and mucous membrane as white-centered petechiae, in the viscera and brain by causing infarction, and in the limbs by producing ischemic pain or gangrene.

In the streptococcal cases there is usually a glomerulonephritis, which often shows focal glomerular lesions as though from minute emboli. However, in cases where the lesion is in a ductus arteriosus, extending to the right side of the heart and with no infarcts except in the lungs, the kidneys may have focal or pure diffuse glomerulonephritis. This type of kidney disease is quite rare in bacillary and even in other coccal types of endocarditis. Renal lesions may still be active in cases in which the heart lesions have become sterile and well healed.

In the acute cases leukocytic reaction is often marked but there is relatively little new fibrous tissue formed at the margins of the lesions With subacute types however a macrophage and fibroblastic response usually predominates There are occasionally many macrophages or giant monocytes in the blood [8,9] and nests of such cells may be found in the myocardium as well as in the richly vascular granulation tissue invading the thrombi on the endocardium [10]

The cases which remain bacteria free so far as blood cultures are concerned comprise 10 to 20 per cent of those with active streptococcal endocarditis They have many organisms in the vegetations demonstrable by culture as well as on direct examination after death These organisms are often close to the surface or on the surface of the vegetations and not simply buried in its depths Their failure to grow from the blood merely shows what high bacteriostatic properties the blood possesses and how ineffective this is in arresting the disease or acting on organisms in the thrombi Yet discouraging as is the clinical experience cases of acute and subacute endocarditis do occasionally become free of bacteria and completely healed scars are found at autopsy often with no history of an illness recognizable as bacterial endocarditis

INCIDENCE

Clinically recognizable cases occur from childhood to senility but there is a sharp peak in incidence between puberty and the early forties In older people the anatomical incidence is still high up into the sixties but many of these either are terminal lesions in other fatal illnesses or are of brief clinical duration dominated by embolic phenomena which can scarcely be distinguished from the vascular accidents due to degenerative disease Bacterial endocarditis singles out the well compensated cases of healed rheumatic heart disease and the functionally unimportant congenital lesions When patients with heart disease decompensate they often have marked malnutrition and obvious damage to the respiratory and digestive tract Yet such cases even when in miserable physical condition retain a remarkable resistance to bacterial invasion of the heart Even in cases of auricular fibrillation without congestive failure bacterial endocarditis is uncommon [11] Severe congestive failure in cases of endocarditis may be precipitated by bacterial destruction of valve leaflets without arresting the progress of the endocardial infection but congestive

failure plays some role in preventing bacterial endocarditis even though powerless to arrest its progress

While there are some who believe this disease is more frequent than formerly a comparison of Harbitz s report (Norway 1886 96 1700 autopsies) with that of Ophuls (California 1900 1923 3000 autopsies) and with our own records for California (1934 38 2300 autopsies) indicates no striking change in relation to total autopsies or to chronic rheumatic heart lesions over a period of 50 years and from 36 to 60° north latitude Clinical recognition is more frequent and each case is probably seen by a larger number of physicians than in the early decades of the history of the disease Marked variations in annual incidence may have occurred in some localities as suggested by Musser (1934)

RECOGNITION

Few diseases assume so varied a clinical course or conceal their true nature more completely behind some sequel appearing to be an unrelated disorder Yet the disease usually follows this simple pattern A young or middle aged person gradually notices a constant disinclination for food work and play, and may be aware of fever irregular or occurring in the afternoon He (or she since the disease is almost as frequent in women) may be unaware of any heart lesion or have almost forgotten the diagnosis made on some prior occasion at any rate cardiac symptoms do not obtrude on his consciousness Tenderness or clubbing of finger tips or petechial lesions may be noted by the patient He may finally take to bed on his physician s orders rather than because he feels quite unable to be up Thus begins a steady failure not unlike that of phthisis but complicated toward the end by embolic accidents—palsies abdominal pain acute bowel obstruction pain and loss of function in arm or leg As in tuberculosis there is usually toward the end at least secondary anemia which may be severe a normal or moderately elevated white blood count rapid sedimentation of blood slight proteinuria

The distinctive features which suggest the diagnosis are the auscultatory abnormalities in the heart a slight splenic enlargement clubbed fingers petechiae and red cell casts or an abnormally large number of red cells in the urine The latter may be demonstrable only when timed urine specimens are examined under constant conditions and the auscultatory findings may not be very striking—merely a systolic murmur

somewhat harsher than is to be expected of a functional murmur due to fever If there are definite diastolic murmurs or a basal systolic thrill the existence of an organic lesion and its probable relation to the febrile illness are at once apparent

In some cases where only an apical systolic murmur is first evident one must have the patient lie supine and *a little on the left side while listening at the apex and about the apical region, in order to hear a diastolic or presystolic murmur* Or it may be revealed when the pulse is slowed by pressure on the carotid bulb The murmur of mitral stenosis *especially in this group of patients often is difficult to detect but repeated* search under various conditions serves to prove that some of the harsh systolic murmurs or very sharp loud first sounds have a diastolic element associated with them Repeated search for conjunctival and buccal petechiae as well as for those on the skin and the observation of clubbing of the fingers must also be stressed in the physical examination

Normal heart size and normal roentgen contours do not rule out bacterial endocarditis but slight cardiac enlargement and abnormal contour, like a harsh systolic murmur may suggest or confirm the diagnosis of organic heart disease on which bacterial infection might be superimposed The constant search for petechiae the repeated and painstaking examination of urine for red cells and of the abdomen for splenomegaly are of particular importance *when the blood cultures are negative, as is true in about one of eight cases carefully studied over long periods of time,* and in a larger proportion of cases in which only one or two cultures are made When the cultures are negative embolic phenomena petechiae glomerulonephritis and splenomegaly in various combinations sooner or later serve to confirm the diagnosis suggested by fever and auscultatory abnormality

While these classical cases with or without positive culture are usually suspected on first examination and proved within a few days the others may for weeks escape detection even by the experienced diagnostician and die before being recognized Some of the pitfalls are best emphasized by contrasting cases of bacterial endocarditis with other types of disease with which they may be confused

Severe gonococcal arthritis A man of 21 developed severe polyarthritis several weeks after the onset of urethritis proved by smear to be gonococcal He ran a febrile course but had only a soft systolic

murmur, no skin lesions. After several intravenous typhoid injections his fever rose to 39.5° to 40.3° C. (103° to 104.5° F.), and after five days of delirium and semi coma, he died. At autopsy no endocardial lesion.

Severe gonococcal arthritis; bacterial endocarditis; erroneous diagnosis of coronary thrombosis. A widow of 52 developed polyarthritis with fever at times. After several months she suddenly had substernal distress and congestive heart failure, with pulmonary edema and hepatic tenderness. The heart sounds were muffled and the rate about 150 when she was brought to the hospital, no definite murmur was recognized. She died within three days of the cardiac accident, and at autopsy was found to have a mild endocervicitis, and gonococcal endocarditis with destruction of one entire aortic leaflet.

Comment: A genteel social position and the relatively benign course of the polyarthritis clouded the recognition of gonococcal infection, the stormy onset of cardiac symptoms suggested myocardial infarction, in severe heart failure, with rapid rate and gallop sounds the diagnosis of valve lesions is particularly difficult.

Pneumococcal endocarditis mistaken for empyema. A man of 56 had a severe and prolonged bout of pneumonia, probably bronchopneumonia although rather extensive in the right upper and middle lobes. The temperature never fell to normal, but began to fluctuate in the second week after a few days in which it rose only to 37.5° C. (99.6° F.). For three weeks he had chills, fever, and subnormal temperature. The roentgen examination still showed haziness on the right, and though there were no definite physical signs, thoracentesis was repeatedly attempted. A systolic murmur, heard throughout his illness, became more harsh, the heart shadow larger. Blood culture, positive for pneumococcus, was obtained on the day of death; the mitral valve was the seat of many cauliflower-like vegetations, and many chordae tendinae were broken.

These examples, taken from cases of rapidly progressive endocarditis due to other organisms than streptococcus viridans illustrate certain diagnostic difficulties. The following case, due to streptococcus viridians, shows that rapid progress, or acute endocarditis, may be due to that organism as well as to those usually considered far more virulent.

Onset of endocarditis simulating typhoid fever. A man of 32 was on his vacation in the country, and at the end of three weeks began to have headache, anorexia, and prostration. Fever was noted on two evenings, and he returned to his home city, entered a hospital. He was apathetic, had a fever which ran between 39° and 39.8° C. (102° to 103.5° F.), but a pulse rate of 100. There was a rather harsh systolic murmur in the

pulmonic area which the patient knew had been noted many years before The white count was 6800 blood culture and Widal negative The spleen was palpable two days later but on the fifth day a second culture yielded many colonies of streptococcus viridans The patient was taken to his home died in less than a month of the onset of symptoms There was no autopsy The diagnosis was patent ductus arteriosus bacterial endocarditis In this case toxemia was more marked and the clinical *duration shorter than in many cases of meningococcus or gonococcus* endocarditis

Undiagnosed endocarditis hemiplegia In a girl aged 18 latent glomerulonephritis with slowly rising blood pressure was followed for three years at 21 the pressure was 140/100 blood urea 50 The patient had a tooth extracted and next day had nausea headache blurred vision She felt achy and ate poorly three weeks after the extraction she suddenly developed *left hemiplegia* On entry two days later there was a spastic paralysis a loud systolic apical murmur scattered retinal hemorrhages blood pressure 140/80 temperature 39 8° C (103 5° F) There was a leukocytosis of 42 000 secondary anemia with hemoglobin 55 per cent Sahli Blood urea 70 mg per cent She died four weeks after the tooth extraction presumably of a cerebrovascular accident On the mitral valve there were two small vegetations with one ulceration through the *leaflet and there were infarcts in brain spleen and kidney Smears of* the vegetations showed streptococci in short chains

Undiagnosed endocarditis uremia Mistaken diagnosis of gastric carcinoma or visceral purpura A printer 44 years old had had rheumatic fever at 17 and later had been refused insurance because of heart trouble He came to the surgeons because of hemorrhoids but he also was very thin and had bleeding gums as well as classical signs of mitral stenosis *However the hemorrhoids were excised on March 11th and* he was seen every few weeks to June 6th because of rectal discomfort On July 20th a friend arranged to have him enter the hospital and then it was learned he had begun to have mid-epigastric pain one hour after meals soon after the hemorrhoidectomy For a month he had been vomiting once or more daily the vomitus was sometimes blood streaked He was very weak at times disoriented The temperature during the six days between entry and death varied between 35 8° and 37° C. (96 6° and 98 6° F) the pulse was 70 to 80 on entry rising to 110 on the day of his death His blood pressure which was 160/90 at the time of his entry in March was now only 110/70 There were many bruises purpuric spots and petechiae on the skin purpuric spots on conjunctivae and in the mouth bleeding gums a red count of only 2 8 M hemoglobin 43 per cent white count 13 000 platelets 60 000 Several examiners at this time could detect only a systolic apical murmur and discounted the

surgeons diagnosis of mitral stenosis The liver and spleen were palpable the liver tender and the urine contained much protein many red cells and white cells By x rays a 40 per cent six hour gastric residue and some irregularity of the first part of the duodenum were noted The heart was not enlarged the left auricle a little prominent Transfusions failed to help and he was comatose for a day before his death The blood urea reported after death was 48 1 mg per cent At autopsy there was a healed and calcified rheumatic mitral endocarditis with very little stenosis vegetations containing streptococci on one leaflet embolism of the left coronary artery with a myocardial infarct severe diffuse acute glomerulonephritis

It is obvious that in none of these cases would correct diagnosis have altered the outcome although it would in one case have prevented repeated thoracentesis in another isolation and special nursing for typhoid fever in a third wearisome gastrointestinal x ray studies and hematological investigations for purpura

Among the conditions with which bacterial endocarditis is likely to be confused are Hodgkin s disease bone abscess undulant fever pyelitis *cardiac infarction meningococcemia and many others Typhoid fever* and tuberculosis however are the two most frequent erroneous diagnoses for this condition It may be complicated by uremia by a cardiac infarct or cerebral accident which overshadows the real cause of trouble it may run an afebrile course Positive blood cultures may lead to an incorrect diagnosis of bacterial endocarditis in cases of meningococcemia pylephlebitis sinus thrombosis infected arteriovenous fistula suppurative arthritis and even pyelitis

Less common than failure to recognize an endocardial infection is an erroneous diagnosis of bacterial endocarditis when the septic focus is not in the heart but the latter error is extremely serious since it prevents the use of therapy which might successfully combat the actual cause of the *fever and bacteremia It is not enough to be on the lookout for bacterial* endocarditis and take blood cultures in all fevers not clearly due to some other disease only a painstaking history and physical examination with indicated laboratory studies will bring to light the other causes of bac*teremia in which with proper therapy* the prognosis is very much better And such a study and careful analysis of evidence is necessary to confirm the diagnosis of endocarditis in the bacteria free stage The latter group

have the same unhappy outcome as those with constantly positive cultures [12, 13]

Especial attention must be devoted to the separation of cases of acute rheumatic fever from bacterial endocarditis In the former the spleen is very rarely palpable, and skin tests with streptococci are usually positive, in the latter the skin tests are negative, the spleen usually palpable Both may have mild joint symptoms, similar fever charts, leukocytosis and rapid blood sedimentation, both have organic heart lesions and varying murmurs, both may pass from compensation to decompensation while febrile [14] Salicylate may relieve joint pains in both, or may fail in either, success with salicylate merely raises the odds against a nonrheumatic lesion just as negative cultures raise the odds against bacterial endocarditis but do not rule it out Abnormal electrocardiograms and especially altered A V conduction increase the probability of rheumatic origin Embolic phenomena occur in rheumatic fever only from mural thrombi in the auricles in cases with severe decompensation, and usually one embolus is enough to decide a doubtful case The combination of bacterial endocarditis and rheumatic fever is fortunately rare, but both acute and subacute cases are reported

MANAGEMENT

The course of the disease may be measured in days or in years, the degree of toxemia and the character of renal and embolic phenomena may vary widely and no specific therapy has been evolved Hence, the treatment of every case must be based on the personality and symptoms of each patient Remissions in symptoms are not infrequent, but 'five year cures' are very rare, and in some of these glomerulonephritis smoulders on toward uremia In spite of the almost certain fatal outcome, prognosis to the family and to the patient should emphasize the possibility of remission and even recovery, and every effort should be made, by agreeable surroundings, diet, iron, vitamin supplements, and especially by repeated blood transfusions, to maintain the patient's physical condition and his morale at the highest possible level Intravenous glucose administration may be of value during critical episodes In this disease one may recall Francis Bacon's aphorism "To brand a disease incurable is to establish neglect and carelessness as if by law."

When the patient is afebrile and feels well enough to enjoy it, *he should be allowed to sit up, to move about even to go out if this can be done without having to climb stairs* Patients should be in bed when febrile but in order to maintain weight and strength they should have frequent change of posture including sitting up in bed or in an arm chair *if that is found to be restful They also require alcohol rubs* and unobstrusive adaptation of the diet to suit each taste and give maximum caloric intake No immune therapy or chemotherapy has been found effective but various members of the sulfanilamide group may be given fair trial [15] Some still use neoarsphenamine or cacodylate in moderate doses repeated small intramuscular injections of autogenous vaccine or *the very expensive treatments* such as immune transfusions if the invalid can well afford them and is of a temperament which withstands patient siege warfare badly but is encouraged by bold forays Fever therapy may be of value in gonococcal endocarditis [16] However no form of therapy which causes obvious disturbance to appetite or well being should be used and more drastic methods should be tried out on the experimental disease in dogs before their trial on patients is justified The awakening of hope in chemotherapy emphasizes the importance of holding out in the siege with our present weapons as long as possible for sooner or later really efficacious methods may be developed for managing such infections

Successes as well as fatal accidents have attended the use of the anti coagulant *heparin in combination with sulfanilamide or sulfapyri* dine [23, 24] Since the prognosis is bad the risk of fatal hemorrhage occurring from what otherwise would be a relatively unimportant infarction of the brain or spleen is a risk now justified by the reports of remissions The treatment is not only hazardous but expensive and therefore can only be advised where optimal conditions for professional and institutional help are available Since reinfection is apt to occur and treatment may have to be given again only a much more reliable and safer type of therapy can be regarded as a satisfactory solution of the problem The reported effects of heparin combined with neoarsphenamine or with one of the sulfanilamide group and given con tinuously for several weeks raise hopes for the early development of a safe cure

PREVENTION

The physician who has an opportunity to follow many patients with fully compensated rheumatic or congenital heart lesions is only too acutely conscious of the fact that year after year some of these people whom he examined only because a murmur had been detected will reappear with an infectious disease over whose relentless progress he has no control. Some cardiologists note on the histories of the patients who have valve lesions, no rheumatic activity, and no signs of cardiac embarrassment, that they are candidates for bacterial endocarditis. Fortunately most of the group live out a normal span or succumb to the other hazards of life without being elected to office, but the cases in whom the sinister prediction is known to be fulfilled within ten years is large enough to make the question of prophylaxis cogent.[17] What precautionary methods are of value, what advice should we give to this group of candidates?

Without giving the patient the quite erroneous idea that he is heading for an inevitable catastrophe, we should inform him (and in some cases his close relatives or employer) that there is as much likelihood of a flare up of infection in his heart as of heart failure at any time in the next three or four decades. In addition to cautioning him against those excessive efforts which impose a great strain on the mechanism of the heart, he should be advised to treat all respiratory infections seriously, to keep quiet and warm until a "cold," whether in the head, throat, or chest, has been entirely well for several days, and to have no operative procedure on the teeth, throat or nose without the advice of an internist familiar with his cardiac lesion.

While only a prolonged series of cases can prove or disprove its value, it seems possible that full dosage of sulfanilamide begun a day before such operations and maintained until the mucous membrane has healed would reduce the risk of endocardial infection. The risk is of course not large for each such procedure, but the consequences of this type of infection are so grave as to make precautionary measures advisable. The ligation of a patent ductus arteriosus has been performed as a prophylactic measure, but until a series of ligated cases has been followed for some years it will not be possible to evaluate this difficult procedure.[25]

For the present prophylaxis consists in minimizing the need for operations about the nose, mouth, or anus, and in early and prolonged care for all intercurrent infections of those whose heart lesions predispose to

this disease Chemotherapy, and the control of acute rheumatic fever offer the great future goals in therapy and prophylaxis

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CHAPTER VII

CARDIOVASCULAR SYPHILIS

By James E Paullin M D and William R Minnich M D

Introduction Syphilitic heart disease is a term which primarily means syphilis involving the aorta There are other parts of the cardiovascular system involved in this disease but the aorta is the one portion of the system which is most frequently damaged and which shows the earliest manifestations of syphilitic invasion

As early as 1728 Lancisi and in 1761 Morgagni suspected the relationship existing between syphilis and aortic aneurysm but the real story of syphilitic aortitis was not written until 1876 when Francis H Welch of England described the gross and histological lesions found in this condition Dohle a pupil of Heller s in 1885 wrote rather comprehensively on the subject and in 1907 Reuter and Schmorl demonstrated the *Treponema pallidum* in the lesions of syphilitic aortitis Since that time much confirmatory evidence has been produced showing the close relation existing between syphilis and a certain type of pathological lesion occurring in the aorta Additional evidence of the part played by syphilis in this condition has been strengthened by the presence of a positive Wassermann reaction occurring in the blood of so many patients with *aortic involvement*

ETIOLOGY

The *Treponema pallidum* is the causative organism of syphilis At the time of the primary infection the treponema enters the blood stream and is distributed generally throughout the body Curiously enough and for an equally unexplained reason the ascending aorta the aortic arch and the entire thoracic aorta seem to be an excellent hiding place for these organisms they collect in the adventitia and the media and may lie seemingly dormant in this location for 10 or 15 years before giving any symptoms or signs which would lead to their discovery

Historical Aspects of Aneurysm

Galen although ignorant of the circulation of the blood did not fail to recognize aneurysm and described two forms—the traumatic and the spontaneous The former no doubt represented the commoner type before the widespread appearance of syphilitic aortic aneurysm in 1495

Fernel first recognized internal aneurysms and suspected their relationship to syphilis as early as 1542 Later Lancisi (1728) emphasized this relationship and published a treatise on both aortic and cardiac aneurysms

Vesalius about 1557 diagnosed both thoracic (and for the first time) abdominal aneurysms

Paré, one of the greatest surgeons of all time noted and in 1582 wrote a detailed treatise upon the vital problem of his day—syphilis and its *association with aneurysm*

As yet there is no very definite evidence to show that there is any generalized active or acute involvement of the aorta during early syphilitic infection, but there are exceptional cases of rather dramatic and disastrous lesions occurring in certain individuals within a year after the primary infection Such a patient was recently observed on our service at the Emory University Division of the Grady Hospital

A colored male single 19 years old was admitted to the hospital in great respiratory distress His *symptoms* began *rather suddenly* on the morning of December 19 1935 While dressing he very suddenly developed marked shortness of breath He started to work but was able to go only a block before he was forced to stop and rest because of severe dyspnea He returned home rested and the next day was able to work He suffered with constant shortness of breath however which soon caused great distress even while lying down he was able to obtain slight relief by *drawing his knees upward towards his chest* Twelve days after the onset of symptoms he noticed a slight swelling of his face and one month after the onset he became so extremely dyspneic that while sitting in a chair he became unconscious and fell out   He was immediately brought to the emergency clinic and was admitted to the hospital

There was a history of having had sore throat at the age of seven years but there had never been any joint pains In May of 1935 seven months previous to the onset of his illness he had gonorrhea and a penile lesion At this time the *Treponema pallidum* was found in the exudate from the penile lesion

On examination his temperature was 37 8° C (100° F) pulse 110 respirations 28 the systolic blood pressure was 110 the diastolic 56 mm of mercury He was a well-developed negro male propped up in bed reclining slightly on his right side with his knees drawn upward He was quite orthopneic There was moderate distention of the veins of the neck and there was *marked cyanosis* of the mucous membranes There were numerous medium and moist rales throughout both lungs more marked over the bases particularly on the right side The point of maximum cardiac impulse was most forceful in the sixth intercostal space 11 cm to the left of the midline although there was a palpable and visible impulse in the fourth and fifth interspaces The entire precordium was thrust forward with each systole At the apex there was a *pronounced diastolic thrill* which was best felt just below the nipple The shock of the first sound was easily felt There was marked enlargement of the heart chiefly downward and to the left At the apex the first sound was loud and booming and was followed by a blowing systolic murmur transmitted upward and to the left The second sound was clear and snapping and was followed by a loud low pitched rumbling diastolic murmur Over

the base of the heart there was a very loud to and fro murmur the louder being the diastolic murmur which was best heard in the second interspace to the right of the sternum The systolic murmur at this area was quite loud rough and of lower pitch than the diastolic murmur The first sound was completely replaced by the systolic murmur which was transmitted to the vessels of the neck The radial pulses were equal regular full bounding and of the Corrigan type There was a distinct capillary pulse and pistol shot sounds were heard over both femoral arteries The liver was considerably enlarged extending 5 cm below the costal border There was no fluid in the abdomen There was a scar on the shaft of the penis The blood Wassermann was positive

When admitted to the hospital the patient was seriously ill His temperature increased he developed signs of terminal pneumonia and died on the third day after his admission

An autopsy was performed 16 hours after death The heart was considerably enlarged markedly dilated and very flabby The tricuspid mitral and pulmonic valves were normal The posterior leaflet of the aortic valve presented a perforation measuring approximately 0 8 cm in diameter This leaflet was thickened and firm The edges of the fenestration were friable and slightly injected At the attachment of the valve there was a small nodule which was slightly swollen hard thick and firm Examination of the aorta just posterior to the leaflet showed a distinct swelling and a tendency to corrugation Sections made through this area showed extensive involvement of the aorta from the intima through the media to the adventitia The intima was thick edematous and swollen and contained numerous round cells and fibroblasts The media was heavily scarred with fibrous tissue and numerous small round cells and plasma cells showing their greatest collection about the blood vessels In the adventitia there were numerous fibroblasts lymphocytes and plasma cells indicating a rather acute fulminating process probably syphilitic. The interesting facts are that this patient received his primary infection in May of 1935 with a positive darkfield examination he developed an acute aortic syphilis which involved only a small area in the aorta but also the posterior leaflet of the aortic valve causing a gummatous degeneration of the valve with perforation within a period of nine months from the initial lesion

PREVALENCE AND DISTRIBUTION

Several years ago it was believed by some that the prevalence of cardiovascular syphilis was increased by the use of arsphenamine The only ground for such a statement would be that in those with primary syphilis too little treatment was given to effect a cure In the present day it is gratifying to see the incidence of this disease decreasing in general hos

pitals, which is probably due to the activity of the Public Health authorities and to the physicians in private practice, who are not only furnishing reliable information concerning the early diagnosis and the sequelae of poorly treated syphilis, but who have also established an acceptable method of therapy for the cure of the disease. Statistical data vary considerably as to the prevalence of aortic involvement in those who have had syphilis. Warthin, from post-mortem experience, is of the opinion that 90 per cent of those with syphilis show definite aortitis. Langer from the Virchow Krankenhaus among 23,105 autopsies on syphilitic persons found from 70 to 80 per cent with cardiovascular involvement. It is true that many of these lesions were minimal and could only have been detected at autopsy. White in 1933 reports 2.8 per cent of syphilitic aortitis in 2100 autopsies at the Massachusetts General Hospital. Cowan and Faulds in 1929 report six per cent in 100 autopsies at Glasgow. At the Grady Hospital in Atlanta during the past five years we have encountered 106 cases among 1837 autopsies.

The clinical recognition of syphilitic aortitis has not kept pace with the incidence discovered at autopsy despite the fact of a greater increase in the efficiency of diagnosis. This, however, is readily explained; when a large amount of autopsy material is studied, it is readily seen that it is an impossibility to detect, from physical or other examinations, the minimal lesions of this infection. Cochems and Kemp among 1000 individuals with syphilis found 12.7 per cent with cardiovascular involvement. Turner among 6000 patients was able to recognize 10.1 per cent with cardiovascular involvement. Such a discrepancy among these data should stimulate all physicians to exert greater effort in the early recognition of this disease and, perhaps still better, to consider that any patient who has had syphilis and who has not had adequate treatment has cardiovascular involvement unless it can be definitely established otherwise.

Congenital syphilis can produce cardiovascular degenerative changes affecting chiefly the myocardium as is shown by numerous case reports. These cases are of more academic than clinical interest since very few so infected survive for any length of time.

AGE AND RACE

Cardiovascular syphilis is much commoner in the South than in other parts of the country, largely because of the negro population and also because of the less common occurrence of rheumatic heart disease.

The factor of age in acquired cardiovascular syphilis is of some importance, as the manifestations usually occur from 10 to 20 years after the primary lesion. This places the greatest age incidence between 30 and 50 years, which is between the age group of patients with rheumatic heart disease on the one hand and the group of those with arteriosclerosis or hypertensive heart disease on the other. The majority of the cases are found in the fourth decade, with the fifth and third following closely. There are, of course, cases occurring in much younger and much older individuals. In the negro race, either on account of a lack of inherent racial immunity or on account of acquiring the disease earlier in life and usually without any treatment, we find cardiovascular involvement occurring at a much younger period. Among the whites as well as among negroes there will be approximately four males to one female. This discrepancy is usually explained by the fact that men perform much more arduous work than women and that there is a much severer strain thrown upon the aorta. However, one must not lose sight of the fact that the promiscuity of the male is much more than that of the female, which makes him decidedly more liable to contract the disease.

Social status is definitely related to the occurrence of syphilitic infection. It is well known that the uneducated and ignorant races are much more prone to have the infection than people of higher intelligence. It is of importance to recall that among the ignorant there is frequently no treatment or only part treatment for this infection and adequate treatment is very rare. Time and close observation alone will tell the effect which intensive treatment will have on the percentage of involvement of the cardiovascular system in syphilis. Moore and his associates are very encouraging by stating that in a series of 117 patients who were treated intensively with three or more courses of arsphenamine and the heavy metals and who have been under observation for nine years, none showed cardiovascular involvement, whereas of 285 patients who had not been so intensively treated but who were likewise kept under observation for this period of time, there were 91 who showed evidence of aortitis or its complications. It is undoubtedly true that the type of work performed plays an important rôle in the progress of aortic disease, in that the more severe and straining the work, the greater will be the damage to the aorta.

PATHOLOGY

Involvement of the aorta is almost the universal lesion in latent syphilis Next in frequency is syphilitic myocarditis and very rarely a localized gumma in the heart muscle The pathological picture of syphilitic aortitis is very characteristic and very seldom mistaken for any other lesion It is one of very marked cellular infiltration involving as a rule all three layers of the aorta and along with this there is a hyaline destruction of tissue with evidence of healing and replacement by fibrous tissue and formation of new blood vessels with resulting scarification

There are many different ideas advanced by various authors as to the mode of infection Some think the treponema is carried directly to the aorta from the primary lesion and that there begins a chronic inflammatory lesion In support of their claims they cite the frequent finding of the treponema in the aorta of patients who died from other causes during early syphilitic infection

Klotz advanced the idea with considerable evidence to support his view that the treponema passed to the aorta through the lymphatics of the mediastinum having been trapped in the mediastinal lymph nodes where they cause a mediastinitis Saphir and Scott and Backhaus are of the opinion that the end result which is medial degeneration is due to an endarteritis of the vasa vasorum produced by a proliferation of the cellular elements within these small blood vessels which interferes with the nutrition of the media

Gross examination of the aorta reveals well outlined elevated gray translucent patches which may be discrete or may coalesce to form larger areas These streaks or patches run lengthwise of the aorta and usually begin just above or at the sinus of Valsalva and proceed upward to the arch involving it and occasionally the abdominal aorta although in most cases of syphilitic aortitis the process usually stops where the aorta passes through the diaphragm This is not always true for occasionally the abdominal aorta alone may be the only part involved Very rarely do these typical lesions degenerate and form ulcers The latter condition is much more commonly found in atheromatous degeneration which may also accompany syphilitic aortitis

If the inflammatory process as it frequently does involves the aorta about the ostia of the coronary arteries serious difficulties arise It is of

interest that the ostia of the coronary arteries may show extensive disease, yet very rarely will the process extend further into the coronary arteries. In some instances there will be found a minimal amount of damage elsewhere in the aorta, the disease being localized chiefly about the ostia and causing either complete or partial occlusion.

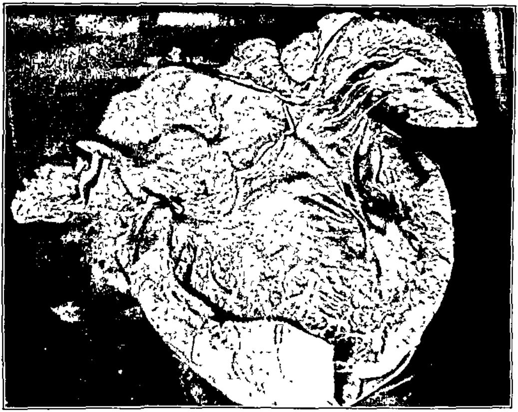

FIGURE 1. Extensive syphilitic aortitis showing a marked "treebark" appearance of the aorta; thickening with deformity of the commissures of the aortic valves producing aortic insufficiency. Localized small areas of aortic dilatation.

The microscopical picture is very characteristic. In the adventitia and about the vasa vasorum in the media one finds a collection of small, round, singly nucleated cells with plasma cells and fibroblasts. This infiltration, beginning in the adventitia, proceeds into the media, where the blood vessels gradually become narrowed and almost completely obliterated. The round cells, the plasma cells, and the fibroblasts so infiltrate the connective tissue and the elastic tissue that hyaline degenerative changes are most marked. One can frequently see strands of elastic tissue that are broken and widely separated from each other, and between these fibers

there is an attempt at healing by replacement with connective tissues. The cells of the intima increase in number and frequently form distinct ridges which project into the lumen of the aorta.

In the media there occur very frequently areas of necrosis with complete destruction of all formed elements resembling small gummata. As

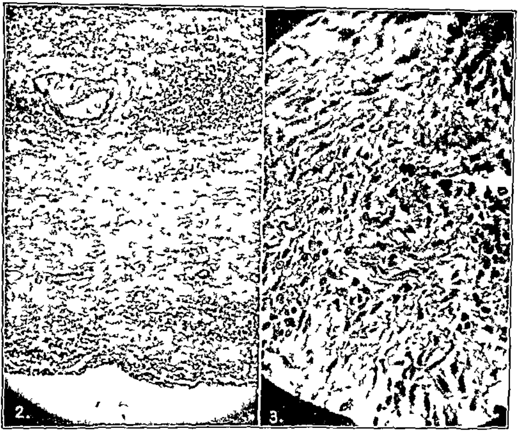

FIGURE 2. Low magnification of a section through the aorta showing infiltration of the adventitia with small round cells, destruction of the elastic fibers of the media, thickening of the walls of the vasa vasorum, marked thickening and infiltration of the intima with small round cells.

FIGURE 3. Higher magnification of degenerative changes occurring in the media.

this destructive process continues the vessel wall becomes weakened and according to the extent there may develop either a small or a large aneurysm. Sometimes the media is completely replaced by fibrous tissue. Should the destructive change proceed downward and involve the commissures of the aortic valve or should it involve the valve itself we find marked retraction, scarification and shortening of the aortic cusps or

dilatation of the aortic ring resulting in aortic insufficiency If the infection is extensive and progresses more or less simultaneously there is generalized thinning of the entire thoracic aorta resulting in general dilatation of the vessel or if the infection is localized there develops a saccular aneurysm which most frequently is found in the ascending aorta although it may occur in any part The most common complication of syphilitic aortitis is aortic insufficiency which is present in approximately 50 per cent of the patients who are correctly diagnosed—very rarely is it seen early in the disease

With thickening of the intima a narrowing or partial obstruction of branches of the aorta may occur This has been mentioned as occurring about the ostium of the coronary artery the innominate the subclavian the intercostal and the carotid arteries may likewise be involved

Syphilis of the myocardium does occur either in the form of a solitary gumma or as a diffuse subacute inflammatory process involving most commonly the left ventricle Gummata of the heart muscle are usually located near the base in the interventricular septum and have the general characteristics of similar lesions occurring elsewhere They are seldom discovered except at autopsy Subacute myocardial syphilis described so well by Warthin and others which perhaps is rarer than other forms of cardiac involvement usually is seen in the left ventricle There is a very *diffuse infiltration of the muscular wall with numerous small round cells* plasma cells fibroblasts and very occasionally a few leukocytes completely separating and destroying the heart muscle These areas are frequently visible to the unaided eye Another lesion probably representing a later stage of this subacute process is found in which most of the active inflammatory process has disappeared and in its place there are large bands of fibrous tissue containing numerous small round cells healing having occurred with complete destruction of the heart muscle in these areas Both types of myocardial syphilis are usually accompanied by syphilitic aortitis

SYMPTOMS

A striking feature of syphilitic aortitis is its latency As a rule there are no symptoms early in the disease and even later there may be no manifestations The early diagnosis of cardiovascular syphilis resolves itself therefore into the early recognition of latent infection of the aorta which would seldom be necessary if every primary lesion received

adequate and continuous treatment When it is possible to make a clinical diagnosis of aortitis we have seen from a discussion of the pathology of the disease that much irreparable damage has been done

Symptoms generally speaking result from involvement of the aorta in one of three ways 1 *The aortic valve or its commissures become diseased resulting in incompetency cardiac hypertrophy dilatation and finally congestive heart failure* 2 Dilatation of the aorta either diffuse or saccular without symptoms or with symptoms resulting from pressure on adjacent organs 3 Involvement of the ostia of the coronary arteries resulting in myocardial ischemia and damage causing pain or heart failure similar to that of angina pectoris The two outstanding symptoms for which the majority of patients seek relief are substernal oppression or pain and paroxysmal attacks of dyspnea

Substernal oppression or pain is frequently an early symptom when the aorta is involved In the early cases pain is not severe and is usually noticed only after unusual exercise It seldom radiates and is localized *beneath the upper part of the sternum it is not an agonizing pain* but more of a pressure or *burning sensation* which lasts for a *short time* and which as soon as there is a period of rest completely disappears The pain frequently is associated with mild dyspnea or slight nonproductive cough In an otherwise healthy individual who has been free from substernal discomfort the onset of pain in the absence of hypertension with a positive Wassermann should make one suspicious of aortic involvement A different type of pain usually accompanies involvement of the ostia of the coronary arteries This comes as a rule with exertion is more intense lasts longer and may radiate either to the neck or to the shoulder it may be accompanied by slight cyanosis and practically always with shortness of breath Occasionally these attacks occur during sleep In the beginning they are spaced at wide intervals but gradually the intervals decrease and the attacks become more severe Very rarely with *these attacks of pain one may observe palpitation of the heart increase in pulse rate and only very exceptionally cardiac irregularity*

Paroxysmal nocturnal dyspnea is given as another time honored symptom of syphilitic aortitis While this symptom is not particularly characteristic of syphilitic aortitis since it is frequently observed in hypertensive and arteriosclerotic heart disease it is of sufficient importance to be suggestive of involvement of the aorta in syphilis A patient with this

symptom may have attacks during the day but they most frequently occur at night

The attacks are quite dramatic coming on suddenly and awakening the patient out of a sound sleep he suddenly rises in bed or stands or goes to an open window He becomes extremely anxious and miserable he breaks out in a cold clammy sweat The respirations are increased in depth and frequency There is perhaps more difficulty with expiration than inspiration The heart rate increases Such attacks occur independent of exertion and last from 5 to 15 minutes gradually subsiding During the height of the attack there is frequent nonproductive cough After the paroxysm subsides the patient frequently returns to bed and again falls asleep

Occasionally the attacks are much more severe and are associated with evidence of marked pulmonary edema and congestive heart failure Between attacks the patient is usually free from all symptoms and is perfectly able to carry on his usual occupation Once attacks of paroxysmal dyspnea manifest themselves they usually increase in frequency and severity until true congestive heart failure results These attacks occur in patients who have uncomplicated syphilitic aortitis as well as in those who manifest other complications of this disease

PHYSICAL SIGNS

On account of the latency of the manifestations of cardiovascular syphilis there may be no physical signs whatsoever and only too frequently is the evidence discovered at post mortem On the other hand with involvement of the aorta one may occasionally find rather obvious signs of the disease The physical signs are those of aortic dilatation which were described so clearly and distinctly by McCrae in 1910 These consist very briefly in (1) an increase in the percussed area of dullness over the upper part of the sternum which is usually most marked to the right of the sternum in the first and second interspaces though occasionally the dullness will extend to the left The heart in practically every uncomplicated case of syphilitic aortitis is normal in size and there is no hypertension (2) In a number of cases there may be seen a pulsation in the first and second interspaces to the right of the sternum or in the suprasternal notch with this there may be observed a slight thrusting forward of the upper part of the sternum (3) Over the aortic area one frequently hears a soft systolic murmur which is transmitted to the vessels

of the neck (4) Of greatest importance is the loud amphoric tambour like aortic second sound heard best to the right of the sternum in the second interspace When obtained this is an extremely characteristic and valuable sign perhaps the most valuable and differs in quality from that heard in patients with hypertension It is generally stated that this is present in practically all cases with aortic dilatation

Additional information is obtained from roentgen ray examination The greatest help is obtained from fluoroscopic examination of the heart and aorta in the anteroposterior the left oblique and the right oblique positions With an experienced observer it is generally speaking easier to detect widening of the aorta to the right of the sternum with an increase of aortic pulsation which is one of the most important roentgen ray signs Widening of the aorta to the left sometimes is quite confusing In the left oblique position a good view of the aorta can be obtained and this is frequently most helpful In a patient with aneurysm the roentgen ray furnishes the deciding evidence in the diagnosis and with its employment one can frequently detect not only one but several saccular dilatations

The electrocardiogram gives very little additional aid in making a diagnosis Smith and Blackford recently studied tracings made from 108 patients with syphilitic aortic incompetency and in comparing these with 900 tracings made from patients with other types of heart disease found that the following changes occurred with significantly greater frequency in the syphilitic group (*a*) Intraventricular conduction defects (*b*) left axis deviation (*c*) low voltage T wave (*d*) S T segment deviation Arrhythmia was rare Transient auricular fibrillation occurred in only 3 1 per cent of the syphilitic group

The Wassermann and precipitation tests of the blood are of considerable value in establishing the presence or absence of syphilis One must realize however that these tests are positive in approximately 80 per cent of patients with syphilitic aortitis and that if the blood reaction is negative one should not dismiss the diagnosis of syphilitic aortitis

COMPLICATIONS

It is unfortunately too true that a great number of patients with cardiovascular syphilis are unsuspected and undiagnosed until some one of the three complications arises The diagnosis then is usually quite

evident, but the patient has reached that stage of his disease when all chances of a cure have gone and when about all that one can hope for is to salvage as much as possible from the wreckage by prolonging life with adequate treatment directed towards the care of the patient, his heart, and his syphilis.

AORTIC INSUFFICIENCY

This is the commonest complication observed. It occurs with a variable degree of frequency in different hospitals, depending greatly on the clientele. During the past four years among 224 patients with cardiovascular syphilis admitted to the Emory University Division of the Grady Hospital, 142, or 63 per cent, had aortic incompetency. A few were admitted to the hospital for other conditions, although the majority came because of congestive heart failure.

Pure aortic insufficiency, occurring between the ages of 30 and 60 years among whites and at an earlier age in negroes, in the absence of a history of rheumatic fever and hypertension is practically always due to syphilis The physical signs are those of aortic insufficiency. There is a diastolic murmur heard over the aortic area. In the beginning of the disease the murmur is very faint and scarcely audible, but with time it becomes loud and rough. At the apex there soon develops a soft systolic murmur in association with the diastolic murmur, which increases in intensity; and not infrequently a very distinct rumbling, presystolic murmur—the Austin Flint murmur—is heard As time passes there ensues cardiac hypertrophy, chiefly of the left ventricle, and the other changes associated with aortic incompetency, viz· (*a*) Visible pulsation in most of the larger arteries, (*b*) Corrigan's pulse, (*c*) capillary pulsation observed in the nail bed, (*d*) marked change in the systolic and diastolic blood pressure with an increase in pulse pressure, and (*e*) pistol shot sounds heard over the femoral arteries.

When there is also some degree of involvement of the ostia of the coronary arteries, though in some cases without any marked involvement, these patients have attacks of paroxysmal dyspnea. Sudden death is not unusual. When congestive heart failure once develops, the condition usually yields to treatment directed to the improvement of the circulation, but on the whole, if a patient lives two years after the onset of this, he is quite fortunate.

ANEURYSM

This is the next most frequent complication of syphilitic aortitis To understand the significance of this complication one must bear in mind that an aneurysmal dilatation may occur at any place in the aorta and may be of any size On the medical service of the Emory University Division of Grady Hospital during the past 20 years there is practically no place in the aorta where we have not seen an aneurysm and these have varied in size from those of 1 to 2 cm to those of 15 to 20 cm in diameter They occur most frequently in the ascending portion of the aorta and the aortic arch next in frequency is the descending and abdominal aorta They are accompanied in about ten per cent of cases with aortic insufficiency Depending on their size and location they may be without symptoms and without physical signs and are frequently discovered only at post mortem

Among our group of 224 patients with cardiovascular syphilis observed during the past four years there were 54 or 24 per cent with aneurysms As a rule they occur singly but fairly frequently they are multiple when more than one aneurysm occurs there is usually one fairly large saccular dilatation accompanied by many smaller ones

ANEURYSM OF THE ASCENDING AORTA

These are usually small and occur intrapericardially beginning in the sinus of Valsalva on the right anterior surface of the aorta or they may originate in other parts of the aorta They are usually without symptoms and without physical signs and are discovered at post mortem in patients who die suddenly with rupture into the pericardial sac At times an aneurysm may extend and cause pressure on the pulmonary artery, giving all of the symptoms and physical signs of cor pulmonale or it may rupture into the pulmonary artery While the aneurysms generally are small they may become quite large increasing to the right and displacing the heart downward and to the left as well as compressing other mediastinal structures or the lung

The following case history illustrates the devastating effect of a small aneurysm with rupture producing sudden death in an otherwise healthy active colored male whose occupation was that of a waiter

The patient 41 years old was admitted to the hospital complaining of pain in his chest He was perfectly well and had not been sick at all until the morning of November 11, 1936 Shortly after dressing he com

plained of a vague pain in the upper part of his right chest He ate a hearty breakfast and reported for work at one o clock feeling perfectly well At two o clock while following his occupation he was seized with a sudden sharp severe intense pain in his chest beginning in the midline just beneath the manubrium radiating downward toward the abdomen and finally becoming very intense in the lower part of his chest and in his upper abdomen Shortly after the onset of pain he collapsed and was admitted to the hospital He gave a history of having had six injections in his arm some several years previously for bad blood

Physical examination revealed a well-developed well nourished negro lying in bed in a state of profound shock He was pale and sweating profusely with cold extremities His general physical examination was negative except for cyanosis His heart beat could not be felt The left border of dullness was increased slightly measuring 10 cm in the left fifth intercostal space The heart sounds were very distant and had a tick tock quality There were no murmurs His pulse was very weak His blood pressure could not be obtained. There was apparently no difference in the pulse felt in the right and left radials There was a feeble pulsation in the femoral artery There was some tenderness and abdominal rigidity in the upper right quadrant The liver was not increased in size and there was no evidence of fluid in the peritoneal cavity His urine contained three plus albumin His leukocyte count was normal His Wassermann was strongly positive

He was given morphine with some relief Local heat and elevation of the foot of his bed made him slightly more comfortable However a blood pressure reading was never obtained His extremities remained cold his cyanosis increased and he had frequent extrasystoles Pain continued but with much less severity He developed a gallop rhythm The abdominal spasticity diminished and within 12 hours after admission he died

At autopsy the ascending aorta and the aortic arch were diffusely dilated Two centimeters above the beginning of the aorta there was a bulging of the aorta approximately 1 cm in diameter and 1 cm deep At the tip of this aneurysm there was a small perforation from which blood had escaped into the pericardial sac. The heart was of normal size The coronary vessels were slightly atheromatous There was a slight thickening about the ostia of the coronary arteries The aortic valves were normal and competent The aorta showed a diffuse syphilitic aortitis for a distance of 5 cm from its beginning to a short distance beyond the left subclavian artery

The following record illustrates the effect of an aneurysm originating in the sinus of Valsalva which pressed on the pulmonary artery and almost completely occluded it

A colored male laborer 32 years of age was admitted to the hospital March 26 1932 with the complaint of short breath pain around heart weakness and swelling all over He had been quite well except for non disabling palpitation of the heart induced by exercise which he had had for the past two years He denied syphilis but had had gonorrhea seven or eight years previously In January 1932 while walking to his work he was forced to stop and rest for a short time because of shortness of breath After resting he continued to his place of business and had no more discomfort until the same night when he was quite dyspneic on lying down From this time he suffered even at rest with dyspnea and paroxysmal attacks of severe dyspnea in which he would go to the window for air with this he began to have pain in the left chest and under the sternum and he frequently had a burning sensation all over the left chest Three weeks before admission to the hospital he first noticed swell ing of his lower extremities which had gradually increased and within a few days involved the entire body There was no history of tonsillitis chorea or rheumatic fever

Physical examination revealed a well developed markedly edematous male negro propped up in bed in great respiratory distress Temperature was 37 1° C (98 3° F) respirations 30 blood pressure 110 systolic 20 diastolic in both arms There was marked dilatation of the neck veins and marked visible pulsation of the carotid arteries Edema of the entire body was most striking There was impairment of resonance with num erous fine râles at both lung bases *Heart*—the entire precordium was thrust forward with each systole The point of greatest impulse was in the sixth interspace 12 0 cm to the left of the midline The percussed area of heart dullness was markedly increased to the left also to the right measuring 5 0 cm from the midline in the fourth right interspace At the apex and over the pulmonic area there was a definite systolic thrill On auscultation at the apex there was a very loud systolic murmur which increased in intensity and was loudest over the pulmonic area a diastolic murmur was heard loudest at the aortic area but both murmurs were easily heard over the entire precordium The pulse was regular equal Corrigan in type The liver was enlarged extending 8 0 cm below the costal margin there was no free abdominal fluid The Wassermann was positive The patient died the second day after admission At autopsy there was an aneurysm originating near the sinus of Valsalva pressing against the pulmonary artery almost completely occluding it Along with this there was a syphilitic aortitis and involvement of the aortic valve

ANEURYSM OF THE AORTIC ARCH

It is difficult clinically to always separate aneurysmal dilatations of the aortic arch into those involving the ascending the transverse and the descending portions only occasionally are these dilatations localized to one portion and very frequently more than one portion is involved in the process

Symptoms and Physical Signs These depend on the point of origin of the aneurysm as well as on its size and the direction in which it grows Some aneurysms give no symptoms whatsoever while others cause a great deal of distress

Pain Is the commonest complaint which varies in its intensity severity and location In the beginning it is a mild but more or less constant discomfort which is not increased by exercise or excitement but which may be aggravated by change of position It is frequently referred to the anterior chest wall to the neck or to the back and occasionally the arm It does not come in paroxysms but is described as neuralgic in type and rarely is it substernal This neuralgic type of pain is frequently followed later in the course of the disease by a constant severe boring pain which causes the greatest discomfort This type is associated with destruction and erosion of bone and is difficult to relieve even with large doses of opiates The milder type of pain is associated with pressure on the nerve roots With rupture there is most intense pain associated with shock

Cough Perhaps the next symptom most frequently noticed is a cough which is nonproductive and frequently only an irritative hack As pressure on the trachea or a bronchus increases sufficiently to cause obstruction the cough increases in intensity and is accompanied by the expectoration at first of a thin mucus later as stenosis increases the discharge changes to a purulent exudate or the expectoration may be bloody There is very frequently a peculiar sound referred to as a goose cough which is associated with paralysis of the left vocal cord

Shortness of Breath This is usually the result either of displacement of the lung in the thoracic cage by the large tumor mass or of pressure on the trachea or the bronchi

Hoarseness This usually occurs when there is enlargement of the aortic arch causing paralysis of the left recurrent laryngeal nerve

Dysphagia: This is not a common symptom and it is usually due to pressure of the aneurysm on the esophagus or is associated with paralysis of the left recurrent laryngeal nerve

Physical Signs: The physical signs elicited in a patient with an aneurysm of the aorta will depend on the location and size of the dilatation. Those commonly observed are as follows:

Inspection. Inequality of the pupils is frequently observed, which is due either to irritation or paralysis of the sympathetic nerves or to involvement of the central nervous system Engorgement of the veins of the neck, arm, or chest, due to pressure of the tumor on the superior vena cava, is sometimes found. Pulsation of the chest wall occurring most commonly in the first and second right interspaces, occasionally on the left side and in the back may be seen At times the tumor erodes the ribs or the sternum and may be seen as a large pulsating mass extending 5 or 6 cm. above the chest wall and covered only by a tightly stretched glistening skin.

Palpation: Deviation of the trachea from the midline and demonstration of a tracheal tug is of much importance. Inequality of the radial pulses and a marked difference in the systolic blood pressure in each arm is of importance. The expansile character of the pulsation is best determined by placing one hand over the suspected area and the other hand at an opposite point in the back. This sign will vary according to the thickness of the clot which fills the sac. A systolic thrill is frequently palpable over the pulsating mass and the shock of the second sound may be felt.

Percussion: The heart is of normal size unless the aneurysm is accompanied by aortic incompetency, or it may be displaced downward and to the left by the tumor mass There is increased retromanubrial dullness and in aneurysms of the ascending aorta this dullness extends further to the right of the sternum In aneurysms of the descending aorta, if the tumor is near the chest wall, definite impairment of the percussion note can be discovered on the left and if near the spine, posteriorly in the interscapular space.

Auscultation: This procedure generally is of very little value; one may hear a systolic murmur over the tumor if the laminated clot in the aneurysm is not too dense. Should aortic insufficiency be present, the usual signs of this are discovered. It should be remembered, however,

that pressure of the aneurysm will occasionally produce the signs of aortic incompetency without involvement of the valve

A rather typical patient is the following A colored male married aged 28 was admitted to the hospital May 13 1935 complaining of pain in left chest and shortness of breath He was perfectly well until the summer of 1931 when he contracted a cold which left him with pain in his upper left chest his upper left back and his left shoulder Shortly after this he became hoarse About December 1 1931 he was awakened at night with a very severe sharp pain in the left interscapular region and left shoulder which caused him to sit up in bed and breathe shallow until the pain subsided After the onset of this pain similar attacks occurred increasing in frequency and severity until January 1935 when he first expectorated a yellowish thick sputum tinged with blood After this his cough improved somewhat but he then began to suffer with shortness of breath so that he could not sleep at night unless he lay on two pillows He continued at his work of delivering ice until April 1 1935 when he was forced to quit because of pain cough and shortness of breath He had pneumonia in 1929 syphilis in 1928 without treatment and gonorrhea in 1930

Physical examination revealed a well-developed and well nourished negro propped up in bed in no great distress The left pupil was larger than the right both reacted There was a distinct tracheal tug and paralysis of the left vocal cord The respiratory movement of the chest was definitely limited on the left side The upper left chest was flat on percussion and the breath sounds and spoken voice sounds were almost absent The right lung was apparently normal There was a distinct visible and palpable expansile pulsation over the upper manubrium and in the suprasternal notch with marked increase in the retromanubrial dullness to the right and left sides The heart was apparently normal in size At the apex there was a soft systolic murmur followed by a loud rumbling diastolic murmur which was heard less distinctly at the base The pulses were equal The systolic pressure was 110 the diastolic 78 mm of mercury in both arms The patient remained in the hospital at rest in bed and showed slight improvement On June 13 he had a hard paroxysm of coughing expectorated a large amount of blood and died rather quickly

At necropsy the whole upper mediastinum was filled with a large aneurysmal sac extending to the left and backward eroding the first and second thoracic vertebrae pressing on the trachea and completely obstructing the left bronchus Rupture of the aneurysm occurred into the left bronchus The entire thoracic aorta was involved there were three aneurysms One of the ascending arch one of the arch and the

other of the descending arch Microscopical examination showed the pathological picture of syphilitic aortitis

ANEURYSM OF THE ABDOMINAL AORTA

This is the rarest type of aortic aneurysm it usually occurs near the celiac axis and causes most of its symptoms from pressure usually on the spinal nerves or by erosion of the vertebrae or by pressure on neighboring structures Pain is usually of the same type and character as is observed in aneurysms of the thoracic aorta The diagnosis is made quite difficult at times unless a definite expansile pulsating mass is felt, differing of course from the normal, pulsating aorta seen so frequently in thin neurotic persons Examination of the patient in the knee elbow position is of great value The intraperitoneal injection of oxygen followed by fluoroscopic examination is occasionally necessary to establish a correct diagnosis

Termination· Most aortic aneurysms terminate in rupture In our experience and that of most observers, rupture occurs most frequently in the following order Into the pericardium pleural cavity trachea and bronchi, esophagus, and then into various other structures Rupture is usually sudden and death occurs within a few minutes or a few hours Occasionally there will be a slow leak into the posterior mediastinal structures, which causes most intense pain and shock When aortic incompetency complicates an aneurysm these patients usually die with congestive heart failure

SYPHILITIC MYOCARDITIS

In the subacute inflammatory lesions occurring chiefly in the ventricles there are few or no symptoms Death usually occurs suddenly Very rarely, however, one may see a patient with an extensive lesion who lives for a few hours and who presents unusual symptoms with few physical signs One such patient has been seen by one of us

A colored male laborer, 52 years old was admitted to the hospital November 20 with a chief complaint of shortness of breath fluttering and burning over the heart He was quite well and was working as a concrete mixer until the morning of his admission On his way to work he suddenly *felt three or four exaggerated heart beats he became quite dizzy*, fell *unconscious in the street*, and was at once brought to the hospital Shortly after admission he regained consciousness and then complained of a marked burning sensation in his chest with sharp pain over

> the lower sternal border radiating to the left side His dyspnea was not very marked Physical examination revealed a well-developed and well nourished male negro, lying flat in bed, in no great distress He was conscious and rational The respirations were 30 to the minute and chiefly abdominal The lungs were clear The cardiac impulse was felt in the fifth intercostal space 11 5 cm to the left of the midline The heart sounds were distant, clear, very rapid and grossly irregular During a period of observation of 10 or 15 seconds the heart rate would reach 160 to 180 per minute to be followed by a very slow rate, 30 to 10 per minute There was a marked pulse deficit with the rapid rate This change in rhythm lasted during the patient s stay in the hospital On the second day after admission he suddenly complained of ' feeling like he was on fire inside around his heart His respirations increased in rate and depth, his pulse became very rapid, he raised up in bed, and fell over dead
>
> At autopsy the heart weighed 610 Gm The left ventricle was thickened and contained numerous round irregular transparent areas from 2 to 6 mm in diameter that frequently coalesced The aorta showed the usual picture of syphilitic aortitis with narrowing of the ostia of the coronaries without aortic incompetency Microscopically the heart muscle in the involved areas was completely replaced by lymphocytes, plasma cells, and polymorphonuclear lymphocytes

Chronic involvement of the myocardium gives very few symptoms and physical signs to suggest its presence Those most commonly observed are slight chest pain, usually burning in character, increasing or noticeable shortness of breath on mild exertion, palpitation of the heart easily provoked by exercise, and, the most valuable of all, cardiac irregularities Norris in reviewing our cases of proved myocardial syphilis was impressed by the variable types of irregularity As the disease progresses, the final picture is that of congestive heart failure without hypertension and usually without heart murmurs, which is unimproved by bed rest or other therapeutic measures

Many authors have described cases of cardiac arrhythmia due to cardiovascular syphilis A few cases of transient auricular fibrillations have been observed in our series, occasionally extra systoles, but generally speaking the presence of cardiac arrhythmia is a point against the diagnosis of syphilitic heart disease in the absence of syphilitic myocarditis Bundle branch block may result from an isolated gumma involving the conduction system

With cardiovascular syphilis there is in about 50 per cent of patients some involvement of the central nervous system. This perhaps is not a complication, but a concomitant disease.

OCCLUSION OF THE CORONARY ARTERY

This complication of syphilitic aortitis occurs rather frequently, but very rarely is the occlusion complete. The pathological process is confined to the ostia of the arteries and very rarely are changes found beyond this point. This lesion is of importance since it may lead to congestive heart failure in the absence of other evidence of cardiovascular syphilis.

The outstanding symptom of this condition is pain, aggravated by emotion or exertion, occurring beneath the manubrium and radiating to the arm, the neck or jaw, and occasionally to the back, resembling in all respects attacks of angina pectoris. The attacks of pain may be mild or quite severe. Shortness of breath or paroxysmal dyspnea is another complaint frequently observed.

There are few or no physical signs. The lesion is frequently accompanied by aortic insufficiency. The electrocardiogram shows nothing of diagnostic importance other than those changes usually observed in myocardial ischemia. Sudden death is not unusual.

DIAGNOSIS

To make a diagnosis of cardiovascular syphilis it is important to be suspicious of its presence in every individual who gives a history of having had syphilis or who has a positive Wassermann. It is admittedly impossible to detect by any means at our command the early lesions of this disease. When symptoms and physical signs are present, a sufficient amount of damage has already been done to the involved aorta to preclude the possibility of cure. *Since it has been definitely demonstrated that involvement of the aorta may occur early, within a year of the primary lesion, it behooves us to remember that there are acute as well as latent manifestations of cardiovascular syphilis.* With these ideas in mind the safest course for physicians to follow with their patients is to make a probable diagnosis of cardiovascular syphilis until it can be proved that they do not have the disease.

Uncomplicated syphilitic aortitis is not always an easy diagnosis to make. It can be made much more frequently if the examiner will take a detailed history and look carefully for the symptoms and physical signs

previously described The diagnosis must not be dismissed as improbable because of a negative Wassermann since such a reaction will occur in at least 20 to 25 per cent of the cases The age of the patient, the absence of hypertension, and a negative history of rheumatic fever are of great help

FIGURE 4 Teleoroentgenogram of the heart showing marked saccular aneurysm of the aorta The heart is normal in size

The criteria for making a diagnosis as listed by Moore in order of their importance are

1 Teleoroentenographic and fluoroscopic evidence of aortic dilatation
2 Increased retromanubrial dullness
3 A history of circulatory embarrassment
4 A tympanitic, bell like, tambour accentuation of the second aortic sound

5. Progressive cardiac failure.
6. Substernal pain.
7. Paroxysmal dyspnea.
8. Pulsation in the episternal notch and a rough, harsh, systolic murmur at the aortic area.

He is of the opinion that "any patient with known late syphilis and without evidence of mitral disease (whether or not the blood Wassermann is positive), the presence of any three of these criteria from 1 to 7 is strong evidence for the diagnosis of uncomplicated aortitis and that the presence of any two of them renders the diagnosis probable."

Other infectious diseases such as rheumatic fever, typhoid fever, pneumonia, and influenza may cause an aortitis, but these complications occur so rarely that they are of little importance.

Hypertension with arteriosclerosis may cause some confusion, it is well known that in some patients with marked hypertension there may be a distinct stretching or slight elongation of the aorta with an increase in the size of the aortic knob. This disease usually occurs at a later period in life and the history, physical examination, and the roentgen ray are of help in differentiation. It should be borne in mind that while there is no evidence that syphilis causes hypertension or arteriosclerosis, there is no reason why a patient with syphilis might not develop arteriosclerosis. It is not an uncommon finding at autopsy to see latent syphilis of the aorta complicated by the presence of many atheromatous plaques.

Aortic Insufficiency: This commonest complication of syphilitic aortitis is usually the one about which there is most doubt as to its cause. Is the lesion due to syphilis, rheumatic fever, or atheroma of the aorta? If the lesion is one of pure aortic incompetency, the chances are that it is caused by syphilis, particularly if it is discovered in a patient over 30 years of age (younger in the negro). In rheumatic fever the heart lesion is discovered much earlier in life. Aortic incompetency due to atheromatous changes in the aorta occurs late in life and such changes are usually part of a generalized arteriosclerotic process. Syphilitic aortic insufficiency is a rapidly progressive chronic complication which produces congestive heart failure in a much shorter period of time than that caused by any other condition.

Aneurysm: This complication frequently offers difficulty in diagnosis As has been indicated small aneurysms originating in or near the sinuses of Valsalva escape recognition Larger dilatations of the ascending transverse, and descending aorta occasionally offer problems for diagnosis, particularly if the aneurysmal sac is filled with a thickened clot which prevents pulsation Fluoroscopic examination of the chest will frequently settle the difficulty although at times there may be a transmitted pulsation from the aorta to an intrathoracic tumor

Bronchiogenic carcinoma lymphogranuloma and dermoid cysts frequently offer difficulties in that they give pressure symptoms and signs not unlike those of aneurysm A careful history and physical examination will frequently clear the diagnosis

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CHAPTER VIII

TREATMENT OF CARDIOVASCULAR SYPHILIS

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Historical Note: Syphilis had been recognized as a cause of cardiovascular disease in the sixteenth century, but it was not accorded due prominence as an important etiologic agent in affections of the heart and blood vessels until the second half of the nineteenth century. As was to be expected, the most obvious form of cardiovascular syphilis, *i.e* aortic aneurysm, was the first to attract attention.

Although aneurysm of the external arteries was described in antiquity by Galen, it was Andreas Vesalius[1] (1514 1564) who in the sixteenth century first recognized aneurysm of the aorta without mentioning, however, *its association with syphilis Ambroise Paré[2] (1510 1590), one of the* contemporaries of Vesalius, first suggested this relationship, but appeared uncertain whether the syphilis itself or the accompanying mercurial cachexia was the responsible factor. The distinguished Roman physician, Giovanni Maria Lancisi[3] (1654 1720), was convinced by his anatomic studies that syphilis played the etiologic rôle and referred to *venereal* aneurysms ("aneurysma gallicum") in his superb monograph published posthumously.

Among the writers of the eighteenth century, Morgagni made numerous and important contributions to the literature of the subject, but for the next three quarters of a century nothing was added, and the earlier teachings seemed practically forgotten. The modern views on cardiovascular syphilis date from the latter half of the nineteenth century with the appearance of the studies of Helmsteder,[4] Welch,[5] Heiberg,[6] Malmsten,[7] and Dohle,[8] and others from Heller's pathologic institute in Kiel The importance and prevalence of cardiovascular syphilis is today a well established fact and it is known to account for from a sixth to a quarter of all deaths from cardiovascular diseases in adults.[9]

FUNDAMENTAL PRINCIPLES

The fact that syphilis of the heart and great vessels is thought of less as syphilis than as heart disease is the source of many blunders in treatment It is therefore necessary at the outset to recall certain fundamental principles of the treatment of syphilis as a disease which govern the treatment of syphilis as applied to its lesions in the cardiovascular system First let it be recalled that syphilis contributes unfavorably to practically all pathologic processes and accordingly treatment for syphilis is indicated in cardiovascular disease whether the syphilis seems causative or merely coincidental The weight of this dictum in pulmonary disease is gradually achieving recognition and in time equal importance will be attached to it even in the management of the decompensated heart in which the clinician too often ignores the syphilis while he prescribes rest sedatives and digitalis The possible failure of such general measures to restore a heart until appropriate treatment for the syphilitic infection has been instituted is demonstrable [10]

The second therapeutic consideration vitally significant in treating cardiovascular syphilis is that of *therapeutic shock* Fast acting treatment for syphilis such as is afforded by the arsphenamines and bismuth especially in large doses gives rise to focal flare ups of the syphilitic process If such flare ups with accompanying edema occur in a partially occluded coronary artery a weakened vessel wall or an infiltrated myocardium or conduction mechanism the gravest results may follow the first or even the first several treatments with the shock producing drug Accordingly it may be accepted as axiomatic that flare ups at active foci in the affected tissues in syphilitic cardiovascular disease must be carefully prevented by a choice of slower acting nonshock producing drugs as preparation for any more intensive subsequent treatment and by a reduced initial dosage whatever the preparation used

The third consideration concerns the induction of so-called *therapeutic paradox* By this term is meant the exaggeration of symptoms and the not infrequent unfavorable outcome which follows the rapid and fibrotic type of healing induced especially by the arsphenamines It is a notable fact that rapid symptomatic response in syphilitic cardiovascular disease may be positively dangerous and that a patient who is up and about or returned to work in six weeks may be quite unnecessarily dead in six months as a result of his therapeutic miracle The making of haste slowly

by selection of methods which avoid rapid myocardial and coronary fibrosis is a fundamental principle in the management of syphilitic heart disease

A fourth group of considerations in cardiovascular treatment as *applied to syphilis is preventive* in nature The impossibility of making accurate diagnoses of incipient syphilitic cardiovascular disease justifies a wider and more intelligent use of the therapeutic test in young persons presenting together with presumptive evidence of syphilis the earliest suggestive indications of aortic disease At this period in the life history of a syphilitic heart or aorta the comparatively greater myocardial reserve the presumed better condition of the coronary vessels and the better general tolerance of treatment by the patient provide a priceless opportunity for arresting an unknown proportion of syphilitic cardiovascular disease in its beginnings It is the duty of the syphilologist therefore to urge upon those who see and study heart as such a greater willingness to perform therapeutic tests for syphilis on early aortic lesions even though as is well known to be the case in syphilitic cardiovascular disease the blood serologic test may be negative It is an indubitable fact that serologic tests may be negative and yet the lesion be syphilitic and respond *to treatment*

In line with the principle of therapeutic paradox there may be noted in the response of a syphilitic aortic lesion the so called paradoxical exaggeration of signs with improvement of the patient s condition For example a diastolic murmur and transient slight dilatation with edema and dyspnea followed by hypertrophy and restoration of compensation may result from the initiation of treatment in a patient who at the outset presented only a systolic murmur in the aortic distribution This paradoxical healing effect is not to be interpreted as a treatment failure but probably as a treatment success

THE APPRAISAL

The first step to precede all treatment for syphilis of the cardiovascular system must be an appraisal of the patient s condition and resources *mental physical material* The weak spots in the treatment of cardiovascular syphilis are the myocardium and the coronaries They more than any other structures limit the choice of treatment agents and affect the prognosis In appraising the myocardial situation electro-

cardiographic studies are essential in addition to the experienced appraisal of the functional capacity of the heart muscle There is no such thing as a distinctive syphilitic electrocardiogram but there is important information to be gained as to the status of the syphilitic patient s heart from this examination Patients with inverted T waves in Lead I and with markedly aberrant Q R S complexes are apt to be hastened to their death by the arsphenamines Prolongation of life and avoidance of discredit for antisyphilitic treatment as applied to the cardiovascular system would follow the use of the slower acting drugs by nonintensive methods in such cases

Patients with syphilitic cardiovascular disease who present anginoid symptoms are particularly candidates for careful study before treatment is begun While they may respond quickly by relief of pain and temporarily increased exercise tolerance too often the early use of an *arsphenamine or even bismuth in such cases is followed by a return of obstinate and intractable angina accompanied by increasing myocardial insufficiency and comparatively early invalidism and death* Therapeutic shock is particularly serious in these patients and often quite unpredictable for autopsy often shows a degree of coronary obliteration out of all proportion to that anticipated from the symptomatology It follows therefore that the detection of evidence of coronary disease is a signal for avoiding therapeutic shock and paradox by resorting to a long and cautious preparation with iodide and mercury or by *extremely small doses* of the arsphenamines or bismuth if they are employed at the outset at all

The tissue reserve of the syphilitic cardiovascular patient must be carefully appraised Here age while not infallible may be a helpful guide The patient who finally in his fifties goes to the wall with a decompensated syphilitic heart has very little recuperative power Much less can be expected of him in the way of treatment response than of the younger patient whose aortic murmur and evidence of syphilis is discovered while his heart muscle is perhaps still far from exhaustion The therapeutic wind then should be tempered to the shorn lamb

Closely related to the foregoing consideration is the appraisal of the patient s probable tolerance of treatment and the order of importance of his symptoms *The patient in whose cardiac syndrome there is a marked element of renal insufficiency will tolerate a properly selected arsphena*

mercury together with an iodide The technic of this procedure is considered under mercury and bismuth Original arsphenamine (606) while the most powerful and effective of all antisyphilitic drugs is usable only in the preventive phase of cardiovascular disease when only the earliest signs have appeared Invaluable though it is the technic of its administration is too difficult for the average practitioner The dumping of too much hypotonic fluid into the circulation and the tendency to vascular reactions such as the nitritoid crisis and to gastrointestinal reactions is too great to make it safe for the advanced case Neoarsphenamine is therefore the preferred drug and if the maximum dosage of 0 3 to 0 45 Gm (5 to 7 grains) be only rarely exceeded even in adult males and the initial two or three doses kept between 0 025 and 0 1 Gm (3/8 to 1½ grains) it gives most of the good effects to be expected of an arsphenamine especially when suitably combined with bismuth

Sulfarsphenamine has the distinct advantage of being usable intramuscularly (there is no excuse for its intravenous use) and hence of being *available in the occasional technically difficult case* as well as being *somewhat freer from therapeutic shock effects* This drug however has been *responsible for a number of cases of hemorrhagic purpura and the incidence of exfoliative dermatitis is much higher than for other arsphenamines For this reason the drug should not be used at all*

Mapharsen or arsenoxide recently added to the available arsenicals appears to be well tolerated and effective so far as the time available thus far permits of judgment It should be used with the same indications and contraindications as neoarsphenamine in a dosage range from 5 to 40 and occasionally as high as 60 mg once a week

Bismuth arsphenamine sulfonate while also responsible for some hemorrhagic complications (as with all the sulfoxylate arsphenamines) is in general quite free from complications and in ten years use has impressed the writers as one of the most eligible of all the group for the treatment of all but the earliest cases of cardiovascular syphilis The fact that it is a chemical combination with bismuth simplifies treatment while enhancing the effect and doing away with the necessity for preparation with mercury and iodide

The following results secured with bismarsen[11] may be taken as fairly typical of good cardiovascular results in favorable cases as secured by the more complicated methods involving preparation with heavy

metals The Wassermann reaction when positive at the start becomes negative after 15 to 30 weeks of treatment in about half the cases Of 14 cases observed from two to three years early marked improvement was obtained in 71 per cent and this improvement persisted in 64 per cent indicating a low incidence of therapeutic paradox in which the improvement would be high at the start but low after a period of observation Of individual symptoms in 30 cases 15 treated by bismarsen alone and 15 by other arsphenamines with heavy metals both technics being equally effective 100 per cent were relieved of pain 50 to 75 per cent of dyspnea 65 to 100 per cent of cough practically 100 per cent of edema and nearly all of palpitation Two of four decompensated cases were returned to full work

Of 16 completely examined patients four developed the paradoxical slight accentuation of signs with improvement in condition spoken of already as an evidence of healing effect Results such as these should be obtainable by any careful technic combining heavy metal preparation and an arsphenamine applied to cases selected for the comparatively good condition of their myocardiums and coronary vessels That they can be obtained by bismuth arsphenamine sulfonate alone is of course an argument in favor of this drug Bismuth arsphenamine sulfonate when thus employed should be given in an unbroken series of from 40 to 80 intramuscular injections the first ten of which are at three to five day intervals the later injections five to seven days The initial dose is 0 025 Gm (3/8 grain) intramuscularly increasing gradually to 0 1 Gm (1½ grains) in 10 to 20 injections

The remaining injections are increased quickly to 0 2 Gm (3 grains) the full adult dose which is then continued throughout the remainder of the series There seems to be no limit to the tolerance of the drug in all but occasional patients and the tonic effect is marked

The action of the heavy metals especially that of mercury is both slower in rate and different in character from that of an arsphenamine Mercury in particular practically never gives rise to significant therapeutic shock effects for its action on the disease is slow and indirect by way of the cellular defense mechanism It does not therefore constitute adequate treatment for early uncomplicated syphilitic aortitis in which there is hope for arrest of the process Mercury by mouth in particular is only allowable in the late cardiovascular wreck whose myocardial and

coronary involvement is such that nothing more effective can be tolerated or as interim rest treatment in patients receiving courses of more intensive treatment Mercury by inunction is a satisfactory method for administration of the drug either alone or as a preparation for later arsphenamine treatment Among the disadvantages of mercury must be included a certain amount of depressant and hemolytic effect especially serious in anemic patients *The bed patient probably gets the best effect from it*

Clinicians too often forget that the inunction is a very slow method of putting a patient under antisyphilitic medication and that it scarcely begins to take effect within two or three weeks after it is begun Accordingly some weeks or even several months of inunctions may be needed for an adequate preparation for either bismuth or the arsphenamines used intensively to produce a curative effect For this reason particularly in the decompensated syphilitic heart the use of a soluble mercurial salt intramuscularly is much more effective than the inunction After digitalis and general measures have failed the writers have known 0 01 Gm (1/6 grain) of succinimide of mercury, daily, or 0 016 Gm (1/4 grain) intramuscularly on alternate days to produce a rapid improvement The insoluble salts of mercury given intramuscularly have lost ground since the advent of bismuth and need rarely be used

Though bismuth cannot yet be considered completely evaluated its use in the treatment of cardiovascular syphilis is being extended The drug is more rapid in action and more shock producing than mercury and less so than the arsphenamines Many cardiovascular cases will undoubtedly tolerate it in full therapeutic dosage from the start but the writers have witnessed a few fatalities following its employment in cases in which shock might occur and have also witnessed decompensation develop during its use in ambulant cases apparently without other explanation They believe therefore that except in those patients obviously able to carry a full treatment regime from the start as in early syphilitic aortitis great caution in the dosage is essential if the morbidity and mortality are to be kept at the lowest possible figure Not more than 0 025 Gm (3/8 grain) of a preparation averaging 50 to 60 per cent metallic bismuth should be given in the first half-dozen injections

Insoluble bismuth salts should be given at four to seven day intervals soluble salts two to four times a week Bismuth makes an excellent combination with arsphenamine therapy and greatly enhances the effect of

neoarsphenamine without increasing toxic effects Neoarsphenamine 0.3 to 0.45 Gm (5 to 7 grains) intravenously can be given simultaneously with 0.1 Gm (1½ grains) intramuscularly of a preparation 50 to 60 per cent metallic bismuth such as the tartrobismuthate of potassium or bismuth subsalicylate to any patient whose condition is such that he can carry the neoarsphenamine alone The combination of bismuth and an arsphenamine in bismarsen as already described is accordingly a highly rational one

Neither bismuth nor mercury in any form should be given intravenously to patients with cardiovascular disease The toxic dose is too near the therapeutically effective dose by this route and the need for time saving can be met satisfactorily by the use of a soluble salt intramuscularly

The iodides have great value in all forms of cardiovascular syphilis If long range constitutional effects are sought doses of 0.3 to 0.6 Gm (5 to 10 grains) of sodium or potassium iodide three times a day may be employed for the resolution of periaortitis however and in vascular syphilis of the brain and cord much larger doses ranging from 2 to 6.5 Gm (30 to 100 grains) of the drug two or three times daily are desirable The digestive disturbance coryza and rash are rarely disturbing factors if the drug is given just before meals in water *not milk,* in a concentration of 240 cc (8 ounces) of water to each 3.3 Gm (50 grains) or less and if the larger doses are begun from the outset and not reached by way of a minute initial dose and subsequent 0.065 Gm (1 grain) accretions There is no object whatever in giving the patient with cardiovascular syphilis sodium iodide intravenously The organic iodine preparations such as siomine and lipoiodine may occasionally be better tolerated than sodium and potassium iodide and a certain amount of iodine effect may be obtained from preparations containing quinine iodobismuthate The writers have seen no clinical evidence of the increased toxicity of potassium as compared with sodium iodide in syphilitic cardiovascular disease

GENERAL TREATMENT MEASURES

It is of course as important to emphasize to the practitioner and the syphilologist that the syphilitic with a heart complication must be managed as a heart case as to remind the cardiologist and internist that the syphilitic cardiovascular patient has syphilis The digitalization and the

management of decompensation of the syphilitic heart should be supervised by one familiar with the general principles. Rest should not only be employed in the advanced case, but it should be made available, or activity should at least be curtailed in the patient with aortitis with valvular involvement while the adjustments in heart load, due to shrinkage of healing valves are taking place. This is usually during the first six weeks to three months of treatment.

The great importance of integrity of the aortic valve in the future of the patient is very apparent in comparing the behavior under treatment of aneurysm and aortic regurgitation. Too much care cannot be taken to insure a slow healing process as compared with a rapid fibrosis and shrinkage with coronary orifice constriction. To secure rest for the syphilitic heart is sometimes rendered difficult by the wreckage of the patient's morale on the familial, social and stigma aspects of his condition. *Time spent, therefore, in adjusting the patient's viewpoint may be as important as drug therapy.* Occupational therapy and progressive relaxation[12] are very helpful. There are no incompatibilities between the sedatives usually employed and any form of antisyphilitic medication. The tonic effect of arsenical treatment sometimes encourages undesirable gains in weight that must be watched.

Relief of pain in patients with repeated *anginal seizures* sometimes becomes a critical matter, and the Jonesco operations[13, 14] upon the cervical sympathetic are, therefore, justified for the control of this particular phase of the problem. There is no more inveterate relapser than the once decompensated aortic regurgitant patient, and preventive measures should be taken, if possible, before rather than after the first breach of compensation has developed. It cannot be overemphasized that it is extremely important to avoid decompensation by every possible means. Restriction of activity at the outset, even to the point of strict bed rest if necessary, permanent adjustments of the future mode of life of the patient, careful and adequate preparation before even semi-intensive treatment is begun, and the assiduous avoidance of reaction producing drugs or dosages. The importance of this is reemphasized by data of the Cooperative Clinical Group[15] which shows that of 281 patients with syphilitic aortic regurgitation or aneurysm, 42 per cent of those in whom congestive heart failure was present before treatment died, and their average duration of life was 30 months, only 24 per cent of those in whom

heart failure was absent before treatment died, and their average life duration was 47 months. In waterlogged cases, the diuretic effect of novasurol, salyrgan, and soluble bismuth salts, such as sodium bismuth tartrate, may be kept in mind.

SPECIAL CONSIDERATIONS

1. **Aortitis and Aneurysm:** In a phase of syphilis in which the keynote should be individualization, it is difficult to propose a system of treatment. It is important, however, that treatment should be prolonged, extending through at least two years. It may be suggested that even in a patient with competent valves and no aneurysmal dilatation, arsphenamine should not be used at the outset because of the possibility of undetectable coronary involvement being present. Treatment may be begun with 8 to 12 weeks of iodide by mouth, given simultaneously with mercury inunctions or mercury succinimide injections or bismuth, intramuscularly, in small doses. This preparatory treatment may be followed, without rest period, by 10 to 12 injections of neoarsphenamine, starting with 0.05 to 0.1 Gm. (3/4 to 1 1/2 grains) and increasing gradually to 0.3 to 0.45 Gm. (5 to 7 grains), depending somewhat on the condition and tolerance of the patient. Alternate courses of bismuth, 10 to 12 injections, and neoarsphenamine, 8 to 10 injections, may be employed over a prolonged period of time, depending on the tolerance and response. It is also possible to give the bismuth and neoarsphenamine simultaneously, at weekly intervals, as above described.

The iodide therapy at the start may be continued for some time after the cessation of other treatment, in periods of two months on and two off. In the patient with aneurysm or aortic regurgitation, treatment must be conservative and lends itself even less well to routinization. If sufficient cardiac reserve cannot be established by the preparatory treatment, it may not be possible to use an arsphenamine at all, except perhaps in the form of small doses of bismarsen. In young persons in good condition with uncomplicated aortitis, neoarsphenamine should by all means be used in an effort to stop the progress of the process entirely. That this arrest is by no means easy is evident from the fact that patients may in the first five years of a syphilitic infection go on to the development of an aortitis in spite of and, in fact, during intensive antisyphilitic treatment. *While it is desirable to reverse the blood Wassermann reaction, especially*

in the earlier cases, it is not justifiable to overtreat the patient in the effort to secure a negative. Much of the best judgment required of the physician in the management of these patients is exercised, especially in their later years, in not doing too much.

Lifelong observation is, of course, an absolute essential in all cases. The management of early aneurysm may be intensive after a period of careful preparation has insured the establishment of therapeutic effect without enlarging the lesion or weakening the vessel wall. An injudiciously treated aneurysm may rupture after the first arsphenamine treatment. Occasionally an aneurysm will reduce in size under treatment, but more often it enlarges, as the periaortitis resolves and comes to a stationary condition, in which it will remain for years without further change if the patient keeps his activities within bounds. During this period of stable equilibrium, treatment should be pushed to meet whatever syphilitic complications there may be and to try to stop the process in the vessel wall. Surgical intervention and the wiring of aneurysms may be considered in rare cases of very large eroding sacs.[16]

The *therapeutic test* in suspected cardiovascular syphilis needs some qualifying conditions. Provocative tests are theoretically rather risky and should be discouraged. A series of serological tests taken after a short course of nonshock-producing treatment is better. At times, the use of the therapeutic test in mediastinal masses is of importance in identifying aneurysm by the development of pulsation in what appears, under the fluoroscope at the outset, to be a solid tumor. For such therapeutic tests, the soluble mercurial salt and iodide followed by bismuth is safer than the initial administration of arsphenamine. Not less than 6 to 12 weeks should be allowed for the resolution of the periaortitis to the point which permits pulsation to appear.

2. Coronary Sclerosis and Myocarditis: If the degree of damage seems considerable or the symptoms clear-cut, it is, the writers believe dangerous to subject lesions of this type to an arsphenamine therapy until after several months of preparation, if at all. The occasional brilliant exception does not offset the high proportion of such cases which, in exchange for a temporary slight gain, months after, when the connection with the previous intensive treatment has been lost sight of, pay the price of rapidly failing hearts. While the outlook of such cases is at best poor, the younger patients sometimes furnish encouraging exceptions and,

after careful preparation can stand the rigors of a course of treatment which at least controls their anginas though the writers have seen no examples of electrocardiographic change for the better In older patients iodide and rest seem the best resorts and if not overtreated the life duration achieved may sometimes quite outrun expectancy

3 Peripheral Vascular Disease Accompanying Syphilis It is out of the ordinary to see peripheral vascular disease in patients with syphilis exhibit more than equivocal therapeutic results It is true however that *hypertension* in the syphilitic patient sometimes undergoes marked and apparently lasting reductions under treatment with the arsphenamines The nature of essential hypertension being so much in dispute and apparently so rarely syphilitic the source of these good effects must remain in question In general it may be said that the hypertensive patients tolerate treatment with the arsphenamines in moderate doses quite well but carry the heavy metals especially mercury with more difficulty The combination of bismuth and an arsphenamine either as in bismarsen or in the combined neoarsphenamine bismuth course already described is probably the best available

Endarteritic processes with *gangrene* and examples of *thromboangiitis obliterans* accompanied by positive blood serologic tests for syphilis do not furnish a very satisfying field for syphilotherapy Almost any form of treatment may produce a transient improvement perhaps nonspecific in origin only to be followed by relapse and progression on which further treatment for syphilis has little or no influence There are however no actual contraindications to an intelligently directed therapeutic test if the Wassermann reaction is positive

Effects of Treatment The Cooperative Clinical Group has recently published a statistical survey[15] of cardiovascular syphilis (based on a study of 619 patients) including treatment results from which the following data are taken

In uncomplicated syphilitic aortitis the average duration of life in patients who died had been increased from 34 to 85 months where adequate treatment (13 or more injections of an arsenical plus interim heavy metal) was given after the diagnosis was made 63 per cent of patients who received adequate treatment were living and symptom free with no progression of the cardiovaasculrr condition at the time of the

study as compared to 49 per cent of those who received inadequate treatment

In patients with syphilitic aortic regurgitation the average duration of life was increased from 40 to 55 months with adequate treatment after the diagnosis was made and symptomatic relief was obtained in 60 per cent of patients who received adequate treatment In the group with saccular aneurysm the average duration of life after detection of the aneurysm was 37 months in patients who had inadequate treatment and this was increased to 75 months in patients who received adequate treatment

PREVENTIVE ASPECTS

The treatment of cardiovascular syphilis like that of neurosyphilis is undertaken years too late Unfortunately the diagnosis of early cardiovascular syphilis is not easy to accomplish and many cases go unrecognized until it has progressed to the stage of aortic regurgitation or aneurysm One aid to the prevention of serious cardiovascular syphilis is recognition of early uncomplicated syphilitic aortitis by maintaining a high index of suspicion and critically evaluating each patient by means of diagnostic criteria such as outlined by Moore Danglade and Reisinger [17] There is no certainty that modern treatment pushed to its utmost can prevent the progress of the disease even at this early stage for examples of progress are seen in spite of treatment The hope is cherished however that identification of a syphilitic infection in the seronegative primary stage before the disease may be said to have gained its visceral and vascular foothold will protect the patient from syphilitic cardiovascular disease It rests with the practicing physician who sees the patient when he presents himself with his chancre and before the appearance of his positive serology and secondaries essentially to modify the relatively discouraging situation with respect to cardiovascular syphilis today That adequate treatment of the patient with early syphilis is in fact a protection in later life is shown by the fact that in the Cooperative Clinical Group material[15] among 333 patients who received adequate and regular treatment during the early stages and who were followed for from 3 to 20 years not one developed any of the graver forms of cardiovascular syphilis By the intelligent and vigorous use of the arsphenamines and mercury or bismuth during the seronegative primary stage in long courses without rest intervals and without regard to the first or sub

sequent negative Wassermann tests (according to the treatment schedule recommended by the Health Organization of the League of Nations[18] and the Cooperative Clinical Group[19]), the practitioner may attack cardiovascular syphilis at its root The rational treatment of cardiovascular syphilis today is the intensive and thorough going treatment of primary and secondary syphilis

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CHAPTER IX

THE HEART IN HYPERTHYROIDISM

By HENRY M THOMAS JR MD

Introduction: Thyrotoxicosis is conspicuous because of its influence on the rate of the heart and many of its most distressing symptoms originate in that organ Death, when it occurs, is often due to heart failure and Moebius[1] said "Die Basedow Kranken leiden und sterben durch das Herz" Viewed from this angle the heart in hyperthyroidism deserves a most careful consideration

In 1786 Parry[2] realized the connection between cardiac symptomatology and goiter, but, to his mind, the heart condition was primary His notes, posthumously published in 1825, include a series of eight cardiac cases in which goiter and exophthalmos were outstanding It is evident that he considered the thyroid and eye changes secondary to the heart disease itself

Adlemann,[3] in 1829 spoke of "Kropfherz," but Graves,[4] Stokes[5] Marsh,[6] and McDonnel[7] four English observers, discussing separately the same group of cases between 1840 and 1855, were still convinced that the enlargement of the thyroid and the exophthalmos developed as a result of the heart trouble Markham,[8] in 1858, reported "affection of the heart with enlarged thyroid and thymus glands and prominence of the eyes"

The surgeon, Rose,[9] working in Zurich, wrote a long paper, in 1877 pointing out the importance of considering the heart in operations on the thyroid gland Forced respiration produced by compression of the trachea by the enlarged thyroid gland, he thought, weakened the heart and finally caused it to fail His method of treatment was to perform a preliminary tracheotomy to relieve the heart of this particular form of burden The classical goiter heart of Rose was thus interpreted as a

heart which had become enlarged and weakened purely through mechanical obstruction

Moebius and practically simultaneously Horsley,[10] and Kocher[11] (vide struma cardiopathica) and F Muller,[12] recognized the part played in this syndrome by the thyroid secretion but, at the time no adequate theory was produced to explain the heart changes Many other writers mentioned cardiac decompensation in patients with large goiters and most of these observations were made in the goiter regions of Switzerland Bavaria and the Tyrol by such men as Wolfer,[13] Wette [14] Thomas Schranz,[15] and others

Finally in 1899 Kraus[16] brought forth his conception of the so-called neurotic or thyrotoxic heart which is now the accepted one in spite of a residue of confusion as to those cases which occur in patients with obviously nontoxic goiters Lack of exact knowledge of the function of the thyroid gland caused him to attempt to include abnormalities of the heart seen in cases of cretinism and hypothyroidism It is likely that authors from goiter districts have continued to confuse cases of myxedema heart with the heart in hyperthyroidism Even as late as 1926 European writers (Meyer and Sulger[17]) have thought of the cardiac disturbances in goiter as due to pressure on the trachea the great vessels or the vagus and sympathetic nerves of the neck Interest, in America is focussed so emphatically on those thyrotoxic cases in which pressure phenomena play little or no part that the writer proposes to omit as irrelevant any mechanical aspects of the enlargement of the gland and proceed to a description of the thyrotoxic heart

DESCRIPTION

Tachycardia is the outstanding cardiac sign *With the patient at rest* the heart rate is often as rapid as 120 to the minute and not infrequently 180 to 200 The tachycardia varies according to the patient s activities although it continues even during sleep The degree of tachycardia parallels in most cases the severity of the disease and a fairly accurate guess as to the amount of elevation of the basal metabolic rate can be made from the resting pulse rate It must be remembered that the resting pulse rate varies in different normal people from a rate of 50 to one of 80 beats to the minute and this same proportionate variation may exist if hyperthyroidism develops so that the pulse rate of the first when

doubled will be 100 while the second will rise to 160 under the influence of the same degree of thyrotoxicosis

In the early stages of hyperthyroidism the tachycardia is not associated with cardiac enlargement murmurs or any evidence of decompensation although extrasystolic arrhythmia does occur quite frequently Later there is enlargement which is due to dilatation with very little hyper trophy With the dilatation come murmurs which are usually character istic of mitral regurgitation (apical systolic murmurs) but which may even simulate mitral stenosis* (apical presystolic murmur and thrill) The heart sounds are loud and snapping the second sound increased and the apex beat is forceful and abrupt The systolic blood pressure is slightly raised and the diastolic pressure lowered giving an increased pulse pressure with a bounding pulse and a visible increase in the systolic excursion of the carotid arteries Pulsation of the liver and even of the spleen have been reported Dilatation of the retinal veins and pulsation of the retinal arteries occasionally may be seen on ophthalmoscopic examination

Finally, in the still later stage there appears auricular fibrillation with myocardial insufficiency orthopnea edema enlarged liver anasarca and cardiac pain Auricular flutter heartblock and bundlebranch block are forms of arrhythmia which also are seen occasionally Electrocardio graphic studies show the presence of the arrhythmias just mentioned and in earlier cases variation in the height and form of the T wave A direct relationship between the height of the T wave and the elevation of the basal metabolic rate has been traced in individual cases but this offers no particular help to the clinician There may be preponderance of one or the other ventricle usually the left

Among the cases which develop auricular fibrillation some show signs of congestive heart failure and others do not Hamilton[19] has stressed this point and carefully described the clinical picture of those with con gestive failure He points out that in his series of 50 cases exophthalmos was usually absent the thyroid gland was often normal in size and tremor and nervousness almost never occurred In recognizing this from other forms of congestive heart failure he stresses (*a*) tachycardia which does

*This latter variety of murmur was shown to me at the Mayo Clinic by Dr Boothby[18] *but several similar cases seen in the* Johns Hopkins Hospital have proven on subsequent postoperative follow up examinations actually to be suffering from rheumatic mitral *stenosis*

not respond as well as should be expected to complete rest and digitalization (*b*) history of unexplained loss of about 30 pounds (*c*) history of a surprisingly long duration of complete disability associated with gross signs of heart failure, (*d*) elevated B M R * (he states that non thyrotoxic congestive heart failure cases may have a B M R of +63, which will return to normal when the heart failure is relieved)

The *average age of this series of Hamilton s cases* was 50 years and most of them were female patients It might be supposed that this group (like many cases of nodular goiter with hyperthyroidism[20] or so-called toxic adenoma) is comprised of patients whose cardiovascular system was previously damaged to a degree whereby slight hyperthyroidism (so slight that the characteristic clinical signs of exophthalmos goiter tremor and restlessness are hardly noticeable) could cause myocardial insufficiency Whatever theories may be held about these cases the fact remains that the only therapeutic solution lies in treating the hyperthyroidism For this if for no other reason an element of thyrotoxicosis should always be suspected in an elderly individual who is suffering from congestive heart failure In the nineteenth century it was fashionable to discuss these cases under the heading of Formes Frustes and more recently cases have been described with normal metabolic rates who obtain symptomatic improvement from iodine medication or from subtotal thyroidectomy The danger involved in such an indefinite diagnostic entity is obvious and the mistakes that I have seen made in this direction lead me to avoid using the term masked hyperthyroidism

If thyrotoxicosis is brought to an end successfully the heart returns to the condition it presented before hyperthyroidism occurred, if the condition runs on death may and frequently does result from heart failure †

In cases of hyperthyroidism showing simple tachycardia the operation for removal of part of the thyroid gland is often followed by paroxysmal auricular fibrillation which may last an hour or two or may go on for a day or two Such a paroxysm usually stops spontaneously without harm but the writer has seen cases in which emboli arose apparently from the fibrillating auricles These paroxysms of auricular fibrillation probably

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*The diagnosis of hyperthyroidism can never be made solely on an elevation of the basal metabolic rate as false high readings are often obtained when patients are emotionally disturbed by worry anger or fright

†Dr J Schranz 1887 Um das Herz dreht sich im der Regel bis zuletzt das Geschick des *Kranken beim Kropf das degenerierte* Herz bringt ihm den Tod

are brought about by the strain of the operation and stimulation from ether on an already overworked and hyperirritable heart muscle which, as pointed out above, is peculiarly likely to develop auricular fibrillation Previously it was thought that handling of the thyroid gland at operation might express an unusual amount of secretion into the general circulation, but the surgical methods in use today practically exclude this possibility. As the irritability of the heart muscle subsides after removal of the source of excess thyroxin the auricles usually revert spontaneously to normal contractions

The early stages of hyperthyroidism are quite indefinite and for this reason the resulting tachycardia may be indistinguishable from "effort syndrome" or "neurocirculatory asthenia." In the later stages the thyroid etiology of the cardiac derangement is quite obvious, although it is frequently difficult or impossible to estimate accurately the degree of underlying cardiac disease which may exist in addition

From the foregoing description of the thyroid heart it will be seen that its chief characteristic is tachycardia which may progress, sooner or later, to auricular fibrillation The explanation of the rapid heart rate is in the process of being discovered. The older theories of cardiac embarrassment from mechanical pressure causing constriction of the trachea, or impaired blood flow through the cervical vessels, or irritation of the cardiac nerves (vagus and accelerator) today have few advocates and are gradually being discarded. Laboratory and clinical experiments have shown that the blood volume is increased in hyperthyroidism and dimished in hypothyroidism,[21, 22] that the minute output of the heart is increased in hyperthyroidism,[23, 24] and more recently that the blood flow is accelerated in hyperthyroidism and slowed in hypothyroidism [25] There appears to be a certain similarity between the so-called beriberi heart and the thyroid heart and Means has stressed the relative vitamin deficiency that may develop in hyperthyroidism in the presence of increased metabolic demands.

No adequate explanation of these facts is at hand, although the ultimate solution will surely depend in some way on the close parallelism between variations in the metabolic rate and in the blood flow. They all afford proof, however, of the increased load borne by the heart in hyperthyroidism. The maintenance of a more rapid flow of a larger volume of blood has been thought to require an increased cardiac

are marked cardiac dilatation and hyaline and fatty degeneration of the muscle fibers

CASE II A. C. Unit No 7767 Johns Hopkins Hospital C F Aet 35 Admitted September 22 1926 Died September 23 1926

F H Negative

P H Struma with no change in size for 18 years

P I Slight shortness of breath commencing seven months ago Eyes noticed to be more prominent Occasionally complained of palpitation Prepared breakfast for husband this morning and seemed all right he returned at 7 P M to find her in collapse—friends say that she was that way all day Sudden onset

P E P 140 Apex rate 210 T 101 R 60 Extremely emaciated restless thrashing about marked exophthalmos Lids fail to close firm smooth enlargement of thyroid Lungs filled with rales C.V Apex beating violently in sixth interspace in anterior axillary line Systolic murmur Auricular fibrillation with pulse deficit of 100 Liver down to umbilicus Pitting edema of legs Died in three hours Pulse became imperceptible two minutes before respirations ceased

Impression Hyperthyroidism Exophthalmic goiter Auricular fibrillation Myocardial failure

Autopsy No 9171 Thirty two hours post mortem The heart is enlarged and weighs 390 Gm The right ventricle is dilated and hypertrophied the left ventricle slightly hypertrophied Microscopically there is definite perivascular and rather slighter intermuscular scarring especially toward the tip of the left ventricle There is no cell infiltration The thyroid is adenomatous The acini throughout appear normal are colloid-containing and lined with cubical cells There are some lymphoid nodules The thymus is hyperplastic Lung spleen and liver show chronic passive congestion This is marked in the liver where there is central atrophy and necrosis

TREATMENT

The treatment of the thyroid heart is in the main similar to treatment of other varieties of heart failure When auricular fibrillation is present digitalis usually exerts all of the benefits seen from this drug in other forms of auricular fibrillation In some cases the slowing effect of digitalis is less marked than in cases of fibrillation uncomplicated by hyperthyroidism When simple tachycardia alone exists even though it may produce evidence of heart failure the use of digitalis is without benefit and its use is strongly questioned by many In the opinion of the writer it should

found that the hypertrophy involved all the chambers of the heart, with a slightly greater proportional increase in the left ventricle. Also, most accounts of the post mortem findings of the thyroid heart describe hypertrophy in a large number of cases, and of 27 thyroid hearts studied in the Pathological Department of the Johns Hopkins Hospital by McEachern and Rake,[32] 16 had definite hypertrophy. Lewis[33] reports 12 cases in all but three of which the heart weighed over 300 Gm. (10 ounces). Means and Richardson[34] also report the necropsy findings in 12 cases Their series showed but little hypertrophy.

The clinical evidence is not clear cut. Hurxthal[35] made careful cardiac measurements on thyroid patients before operation and again three months after operation. He found no contraction in the size of the heart, from which he inferred that there had been no previous enlargement He further compared 100 cases of toxic goiter with 100 cases of the nontoxic type and, after making correction for the transverse diameter of the chest and body weight, he concluded that the average transverse diameter of the heart in the toxic group exceeded that of the nontoxic group by only 0.49 cm Friedberg and Sohval[36] (1937) reviewed the subject of cardiac hypertrophy in Graves disease. In 27 fatal cases of hyperthyroidism studied at the Mt. Sinai Hospital hypertrophy was found in 14, but 12 of these suffered also from hypertension or severe coronary sclerosis or established auricular fibrillation. The remaining two cases showed hypertrophy of "very slight degree" independent of the various pathological states just mentioned They believe that tachycardia compensates for increase in minute output of blood by the heart in hyperthyroidism and that the output per beat is not increased and therefore dilatation does not occur in uncomplicated cases.

Theoretically it is important to discard hyperthyroidism as a cause of enlargement of the heart, but one sees the combination so frequently that its occurrence requires practical consideration In the light of our present knowledge we must conclude that enlargement of the heart in uncomplicated cases of hyperthyroidism has not been proved. When congestive failure exists, from whatever combination of causes, dilatation of the ventricles occurs and this dilatation may disappear entirely when the hyperthyroidism has been allayed. The following case illustrates this statement.

CASE I Mr G aged 44 years Occupation Railway track laborer Admitted to the Church Home and Infirmary December 30 1926

Nervousness and prominence of the eyes had been first noticed about 14 months before admission Five months previous to admission (March 1926) a local physician had diagnosed his case as exophthalmic goiter but he was given no treatment In April he suddenly lost his voice and

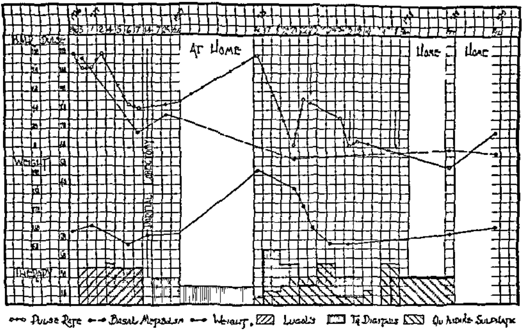

CHART 1 CASE 1 Following the partial lobectomy the patient insisted on returning home before the auricular fibrillation had been interrupted During the 13 months at home on digitalis under the direction of his local physician he continued to fibrillate and gradually went downhill During his second stay at the hospital on rest digitalis and quinidine he excreted 33 pounds of fluid in eight days and reverted to normal rhythm on the eighth day Since September 12 1928 he has done full manual labor as a track man on the railroad without the loss of a single day from sickness and without taking either digitalis or quinidine (Thomas Bull Johns Hopkins Hosp)

this condition lasted three months after which it gradually disappeared During the summer months the nervousness increased and he had several attacks of diarrhea His wife noticed that his appetite was abnormally good but that he was becoming tremulous About seven weeks before admission dyspnea orthopnea and palpitation became very marked and there was some cough and slight swelling of the ankles There was no past history of tonsillitis chorea rheumatism or symptoms suggesting syphilis the only previous illness being typhoid fever in 1916

Physical examination A well-developed man of 44 years, weighing 160 pounds He was very restless although not apprehensive His skin was flushed and moist There was an extreme degree of exophthalmos of both eyes which had resulted in an inflammatory condition of the con

junctivae The thyroid was diffusely enlarged rather soft in consistence with no thrills or bruits Cardiac dullness measured 5 cm to the right of the midline and about 9 cm to the left The sounds at the apex were quite irregular (108 to the minute) and a systolic murmur was heard The sounds at the base were irregular no murmurs There was a pulse *deficit of 17 beats to the minute Blood pressure 150/70* Lungs clear no rales at the bases Liver not felt Marked tremor of the extended fingers Slight edema of the ankles

Basal metabolic rate 95 per cent above the average normal for his size age and sex (December 31 1926) Urine Acid 1 020 Alb + Sug 0 Micro Normal Hemoglobin 95 per cent

Course in Hospital Digitalis therapy was instituted and Lugol s solution 0 6 cc. (10 minims) t i d was given Marked symptomatic improvement took place with a corresponding fall in the basal metabolic rate to +32 on January 6 (weight 154 pounds) and to +14 on January 11 (weight 158 pounds) On January 11 a subtotal thyroidectomy was performed by Dr W F Rienhoff Jr without altering the patient s condition to any extent The Lugol s solution was discontinued (as is our usual procedure) and 11 days after the operation the B M R was +35 per cent Auricular fibrillation persisted but the patient was forced to return to his home in West Virginia on January 26 From the history of his symptoms during the next 12½ months it seems evident that auricular fibrillation persisted uninterruptedly He took tincture of digitalis under the direction of his local physician In May he resumed his work but he could not do more than pump the handcar out to work and he often became short of breath He was somewhat better during July but in August he began to get nervous and run down and could not walk 300 yards without breathlessness He rested during September and improved slightly but could only perform an occasional day s work during October November and December Some time about the middle of December his condition began to go downhill and in February he noticed a good deal of swelling of the legs

On his return to the hospital February 15 1928 he presented the picture of severe cardiac decompensation with auricular fibrillation cardiac dullness 4 cm to the right and 19 cm to the left in the sixth inter costal space Blood pressure 112/85 As the time the patient could stay in the hospital was extremely limited digitalis and quinidine therapy were started simultaneously and eight days later during which time he had lost 33 pounds the liver had become normal in size and the pulse regular in force and rhythm During the following week he continued *to excrete the edematous fluid until at the end of 14 days admission he* had lost 12 pounds Auricular fibrillation reappeared when the dose of quinidine was reduced but normal rhythm was permanently restored by

adding a dose of quinidine at midnight The patient was discharged on March 24, 1928

He returned to Baltimore on June 7 1928, for examination He said that he had taken tincture of digitalis 0 6 cc (10 minims) t i d and quinidine sulfate, 0 3 Gm (5 grains) t i d and at 11 P M regularly and had had no return of the irregular pulse His strength had gradually increased so that he felt he was ready to resume work He looked quiet and strong There was no edema liver not palpable no rales at the lung bases. Heart dullness 2 cm to the right and 13 cm to the left with a short soft systolic murmur heard at the apex Sounds regular and of fair quality although the first sound was somewhat muffled at the apex B M R — 1 per cent Weight 157 pounds

Electrocardiograph June 7 1928 Rate 67 rhythm sinoauricular P R interval 0 23 second T I II and III inverted The first degree heart block as well as inversion of T I and II and the sinus arrhythmia are almost certainly due to the amount of digitalis he has taken

Teleoroentgenogram MR 5 ML 9 T 30 Aorta slightly dilated

The effect of exercise does not pass off as rapidly as is usual (pulse rate of 90 to 95, 15 minutes after hopping 50 times)

The patient returned home discontinued all medication and three weeks later began work in the garden He gradually increased his daily work until on September 12 1928 he returned to his full work as a track man on the railroad Since that time he has done full manual labor without the loss of a single day from sickness He arises at 5 A M makes the fire milks a cow breakfast at 6 walks a mile to work which begins at 7 30 and lasts until 5 has a half hour for lunch During this time the work is fairly constant with a pick or shovel He usually returns home in a machine and retires at 8 P M He has noticed no swelling of the feet no shortness of breath or irregularity of heart action his appetite has been very good but not excessive and his weight has remained constant At my request the patient returned for examination

Physical examination March 2 1929 Five feet 11 inches 162 pounds There is quite definite exophthalmos not as marked as on the previous examination but still very evident The sclera of the left eye is injected conjunctivae not inflamed

Thyroidectomy scar barely perceptible No thyroid tissue felt

Lungs clear to percussion and auscultation no rales at the apices or bases

Heart The apex is not clearly seen or felt Dullness extends 8 cm to the left of the midsternal line 2 cm to the right No increase in dullness at the base At the apex the sounds are clear, of good quality, no murmurs No murmurs at the base

Pulses are equal and synchronous and regular in force and rhythm, 17 to the quarter The vessel wall is not thickened brachials not tortuous Blood pressure 120/80

Liver not felt nor enlarged to percussion Spleen not felt

Extremities No edema of the ankles, no fine tremor of the fingers

B M R, —7 per cent

Urine Negative

Electrocardiograph March 2, 1929 Rate, 76 Rhythm sinoauricular, P R interval 0 30 second Remarks T waves all upright P II diphasic Diagnosis Normal sinus rhythm

The first account to be given of the pathological changes in the heart of a patient who died of thyroid disease was by Sir Henry Marsh,[6] in a report before the Pathological Society of Dublin, in 1841 Before death, this patient had suffered from irregular heart action and anasarca The heart was greatly dilated, particularly on the right side, showed some hypertrophy and granular fat along the margin of the mitral valve Since then various reports have been made noting changes in the heart muscle and these reached their high point with Goodpasture's[37] account of two cases which showed degeneration and fragmentation of the heart muscle fibers *Recent careful pathological studies have failed to reveal any constant or clearly proven pathological change in the heart which is definitely caused by hyperthyroidism*

EFFECTS OF THYROTOXICOSIS

Clinically it is thought that thyrotoxicosis produces no lesions which are permanent in their effect and patients are seen who suffer for several years from the most extreme form of heart failure and then return to perfect functional activity of the heart after subtotal thyroidectomy [38] Even in those patients who die quite evidently from heart failure the myocardium frequently reveals no changes demonstrable by present methods of pathological examination From a careful reexamination of the hearts of 27 patients dying with hyperthyroidism at the Johns Hopkins Hospital it was concluded[32] that no pronounced pathological change is produced in the heart by hyperthyroidism Current opinion then is that the hearts of patients dying from thyrotoxic heart failure show a variety of inconstant minor lesions none of which can surely be ascribed to hyperthyroidism The changes most frequently encountered

are marked cardiac dilatation and hyaline and fatty degeneration of the muscle fibers

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TREATMENT

The treatment of the thyroid heart is in the main similar to treatment of other varieties of heart failure When auricular fibrillation is present digitalis usually exerts all of the benefits seen from this drug in other forms of auricular fibrillation In some cases the slowing effect of digitalis is less marked than in cases of fibrillation uncomplicated by hyperthyroidism When simple tachycardia alone exists even though it may produce evidence of heart failure the use of digitalis is without benefit and its use is strongly questioned by many *In the opinion of the writer it should*

be withheld from these cases until after operation or until some other indication for its use arises For the same reasons venesection is rarely a helpful procedure

Quinidine is most valuable in obtaining reversion to normal rhythm in cases of auricular fibrillation which do not revert spontaneously after operation It should not be used before operation because the slowing effect that digitalis has on the fibrillating heart is lost after normal rhythm is established by quinidine and dangerous tachycardia may ensue

CASE III Mrs A P Aged 31 Hospital for the Women of Maryland No 3-406 March 12 1931

Complaint Nervousness palpitation shortness of breath

P H History of occasional sore throat No serious illnesses Weight Best 165 pounds Now 160 pounds Nerves Has always been nervous and high strung More irritable the past year

Swelling of the neck was noticed nine years ago but symptoms began four years ago with attacks of pain in the left chest palpitation and dyspnea In the past year she has become more nervous and irritable and has lost weight in spite of an increasing appetite

P E Patient is a nervous restless white woman sitting up in bed with some shortness of breath Well marked exophthalmos and lid lag Thyroid gland is diffusely enlarged with some lobulation Heart Sounds are absolutely irregular Apical rate 130 At the wrist 105 to the minute There is a loud blowing systolic murmur over the precordium Diastole is clear Blood pressure Sounds come through first at 160 mostly at 145 Diastole 90 There are a few rales at the bases Abdomen Negative Liver and spleen not felt Slight edema of the ankles

After two weeks of Lugol s solution the B M R fell from + 59 to + 13 and she was operated on by Dr William F Rienhoff Jr on March 28 1931 She improved postoperatively but auricular fibrillation persisted and 12 days after the operation she was started on quinidine sulfate and the dose increased to 0 6 Gm every six hours Eight days later the fibrillation disappeared and normal mechanism was reestablished with the apical and pulse rate of 52 beats to the minute She was discharged five days later on the maintenance dose of quinidine 0 2 Gm at 7 A M 2 P M and 9 P M After two weeks home the quinidine was stopped Normal cardiac mechanism was permanently established

Symptomatic improvement is noted following treatment in an oxygen tent When all is said and done the ultimate and only lasting treatment is removal of the cause that is the hyperthyroidism Surgical removal of a large portion of the thyroid gland offers the best results and this

may be done no matter how serious the cardiac symptoms seem to be Formerly the operation of thyroidectomy was considered very dangerous particularly in cases suffering from congestive failure The preoperative use of iodine and the improved operative technic and postoperative care have changed this point of view however and now surgeons do not hesitate to perform total thyroidectomy on desperately ill rheumatic or arteriosclerotic cardiac cases In our clinic we have seen little temporary and no permanent improvement in cardiac cases without hyperthyroidism and the procedure is rarely employed

Preoperative treatment with iodine causes a specific reduction in the functioning of the thyroid and while this is only temporary it is to all intents and purposes similar to the removal of a portion of the gland Auricular fibrillation has developed in elderly patients with nodular goiter with hyperthyroidism when at rest in bed under iodine treatment Friedrich Muller once stated to the writer that iodine occasionally exerts a deleterious effect on the heart muscle of some such cases This has never been corroborated by experimental observations but the writer thinks that such a possibility should be borne in mind

Occasional refractory cases are seen in which iodine fails to bring about improvement and in these ligation of one or more thyroid arteries may be resorted to This simple procedure tends to reduce the thyroid activity and thus permits an improvement of the myocardium sufficient to allow the operation to be borne safely A complete subtotal lobectomy should never be undertaken in the difficult cases until the patient s general condition (*i e* B M R nervousness body weight etc) and with this his heart muscle has been sufficiently improved

The choice of anesthesia for thyroid operations in patients with heart failure deserves careful consideration Because of the dangers of open drop ether anesthesia much attention was paid some years ago to developing a smooth local anesthesia method With the improved methods of closed ether and oxygen anesthesia with gas induction the need for this has disappeared in all but the most desperately ill patients Careful ether anesthesia preceded by light basal anesthesia or avertin or sodium amytal is the method preferred by Rienhoff in the Johns Hopkins Hospital Lahey[39] advocates the use of cyclopropane combined with nitrous oxide since cyclopropane alone is likely to produce undesirable cardiac irregularities The danger of bringing on these cardiac irregularities is offset

Lahey believes, by the absence of the excitement stage and of post operative vomiting

In some clinics sodium amytal (0 39 Gm. (6 grains) one hour before operation) and morphia (0 01 Gm ($\frac{1}{6}$ grain) with strychnine 0 6 mg. ($\frac{1}{100}$ grain) a half hour before operation) are used as a basal anesthesia followed by ethylene in the operating room. We have found a great many hyperthyroid patients who are sensitive in one way or another to morphia and so we now take the precaution to give them a test dose several nights before the operation Pantopon, 16 mg. ($\frac{1}{4}$ grain), can be substituted in sensitive individuals Experienced anesthetists vary in their preference of methods depending on the technic with which they are most familiar The combination ether method has the one indispensable *advantage of keeping the depth of anesthesia constantly under control*

It may finally be concluded that the heart, in conjunction with the rest of the body responds to hyperthyroidism by functional acceleration Given a normal young cardiovascular system this speeding up is a matter of little or no consequence On the other hand, in a heart which is weakened by advancing age or heart disease the constant overwork from hyperthyroidism frequently leads to congestive heart failure In either instance removal of the hyperthyroidism allows the heart to regain both functionally and structurally its prehyperthyroid condition

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CHAPTER X

CARDIAC NEUROSES

By LEWIS A. CONNER, M.D.

Definition. The term "cardiac neuroses" is the one commonly applied to a large and heterogeneous group of disorders characterized by cardiac symptoms which obviously are not due to organic disease of the heart or of other organs.

In its broadest application the term includes disorders due to such widely diverse causes as emotional disturbances, fatigue, exhaustion following acute illness, toxic agents such as tobacco and coffee, reflex disturbances from other organs such as the stomach and gallbladder, and even disorders of thyroid function. So distinct a cardiac syndrome as paroxysmal tachycardia has sometimes been included among the neuroses, although its true nature is still obscure.

Without attempting to define boundaries to the proper application of the term cardiac neurosis, the present discussion will be limited to the consideration of disorders in which the cardiac symptoms are associated with and in large part are occasioned by emotional disturbances. The reason for thus restricting the discussion to this limited interpretation of the term lies in the fact that it is to this type that most of the serious and therapeutically difficult disorders belong. Such minor neuroses as occasional extrasystoles and transient palpitations are usually negligible unless or until they are associated with such emotional factors as apprehension and anxiety.

ETIOLOGY AND PATHOGENESIS

Every one is familiar with the fact that the emotions have a direct influence on those bodily functions which are controlled by the vegetative nervous system and whose workings normally proceed without participation of the conscious mind. Their influence on the secretory functions need but be recalled, as exemplified in the flow of saliva and gastric juice

called forth by the mere sight of appetizing food their effect on the musculature of the gastrointestinal tract as shown by the vomiting excited by some revolting sight and by the diarrhea caused by fright or anxiety their influence on the walls of the arteries as displayed in the flushing of embarrassment and the blanching of fear and anger The rare but well authenticated instances of jaundice following some violent emotion are to be explained probably as the result of spastic closure of the sphincter of Oddi Finally the influence of the mind on the action of the heart is shown by the tachycardia the palpitation the premature beats and the precordial discomfort produced by sudden fright or violent anger

For a full realization of the far reaching influences of the emotions on the bodily functions one should read Cannon s illuminating book Bodily Changes in Pain Hunger Fear and Rage [1]

This influence of the emotions on the visceral functions is obviously exerted through the medium of the autonomic nervous system since these organs are innervated only by that system but the effects may be produced either by the direct action of the vegetative system on the respective organs or indirectly by its effect on the glands of internal secretion such as the suprarenals

For present purposes neuroses in general may conveniently be divided into those disorders in which the symptoms are chiefly or wholly those of disturbed states of mind—the psychoneuroses—made up of morbid fears apprehensions anxieties indecisions and depressions and those in which the chief symptoms are due to disturbance of the functions of one or more of the internal organs—the so called organ neuroses or the vegetative neuroses In the one case the victim may have a distressing fear of for instance heart disease without any actual symptoms referable to that organ In the other he may have obvious symptoms and signs of disturbance of the cardiac functions without for a time at least any conscious apprehension or fear When however the disorder has existed for some time it is usual to find both types of symptoms present and operating as a vicious circle every appearance of a cardiac symptom serving to increase the mental agitation and this in turn increasing the tendency to cardiac symptoms

From what has been said then it is obvious that the cardiac neuroses are merely a special type of that commonest of all forms of neurosis—the anxiety neurosis

The psychic reaction to doubt concerning the integrity of the heart seems to be much more violent and profound than is the case with any of the other internal organs Most persons who would accept with considerable equanimity the knowledge that they had some disease of the liver or kidneys or lungs will have their morale sadly shaken by any evidence that the heart is not functioning properly In the minds of most laymen the thought of heart disease is still associated with the idea of sudden and unforeseen death This is probably the reason why the cardiac neuroses occupy such a prominent and important place in the list of organ neuroses

For the normal functioning of the organs under the control of the vegetative nervous system there is maintained a fine balance between the accelerator and the inhibitory mechanism by which such functions are carried on without participation of the conscious mind But all these functions are nonetheless to some degree susceptible to psychic influence Transient disturbances of this equilibrium occur as has been pointed out in normal individuals as a reaction to sudden psychic stimulation In the neurotic individual this response on the part of the vegetative nervous system seems grossly exaggerated and out of all proportion in its severity or its duration to the psychogenic stimulus Such excessive reactions are apt to be thought of in terms of a hypersensitive autonomic system or of autonomic imbalance The question may be raised however in most such instances whether the fault does not lie in a psychic stimulus which is excessive or unduly protracted rather than in an abnormally sensitive autonomic system

If the premise of a psychogenic basis is accepted for all the cardiac neuroses in which toxic or reflex causes may be excluded then it must be admitted that such a psychic origin is sometimes so obscure and so deeply buried as at times to defy the most thorough search and questioning Neurotic patients are notoriously prone to suppress and conceal their unreasonable fears and anxieties even when these still occupy the conscious mind but in many cases the stimulus may lie in some long past experience which has disappeared from the conscious mind and has sunk into the subcortical autonomic zone where it remains only as an organ memory *Nevertheless it may be stated with some confidence that the frequency with which a psychic cause is established will vary directly with the thoroughness and skill with which it is sought*

But even though a careful search may fail to reveal a direct and obvious relationship between the cardiac symptoms and some definite psychic disturbance it will rarely fail to disclose evidences of some instability of the nervous system as it relates either to the mind or to the autonomic mechanism It is surprising in reviewing the history of patients with functional heart disturbances to find how frequently the story of some nervous breakdown is obtained either during the years of school or college life or in the course of some later period of stress

In other patients without such a definite breakdown there will be indications of mental instability becoming apparent in the form of exaggerated introspection of great suggestibility of morbid concern for health In still others there will be a history of other organ neuroses or clinical evidences of a disturbed autonomic nervous mechanism such as instability of vasomotor control extreme lability of the pulse rate or blood pressure level or marked sinus arrhythmia

When the psychic stimulus can be determined it will usually be found to fall into one of the following four groups of causes

1 The statement of some physician or life insurance examiner that the heart shows some abnormality such as a murmur or irregularity of rhythm or else the rejection of the applicant for life insurance on the score of some heart disturbance or of high blood pressure Sometimes it is a mere assumption on the part of the applicant himself that the heart must be diseased because two or three examiners were called in to listen to it *In a person of the appropriate mental composition the slightest suggestion that the heart is not intact may be enough to start a whole train of emotional reactions leading up to cardiac symptoms*

2 The occurrence of some dramatic case of heart disease (perhaps *with sudden death*) *among the relatives or friends of the patient*

3 The appearance of some symptom which calls the attention of the patient to his heart and leads to a doubt as to its integrity This may be a sudden skip a flutter or a twinge of pain or may be merely what is regarded as undue palpitation or dyspnea after some special exertion Such disturbing symptoms are often first noticed during convalescence from an illness such as an attack of grip or they may appear as a result of the excessive use of tobacco or coffee

4 Some profound and protracted emotional disturbance such as deep grief or prolonged anxiety or excitement in which however there is at

first no element of doubt concerning the state of the heart Much the most striking illustrations of the operation of this cause were seen during the war in the innumerable instances of that condition known variously as the irritable heart of soldiers the effort syndrome or neurocirculatory asthenia As the result of the profound and long-continued emotional disturbances incident to the process of volunteering or of being drafted into the army such cases were encountered literally by the thousand and far outnumbered all the cases of organic heart disease found by the examining boards

SYMPTOMS

These are predominantly of a subjective character as is the case in most other forms of organ neurosis Such subjective symptoms include every possible variety of sensation from that of a slight fullness soreness or pressure up to severe anginal pain with its characteristic localization and its radiation to the arm neck or back Frequently the sensation relates to the heartbeat and is described as fluttering palpitation pounding or throbbing in the ears or temples A common form of unpleasant sensation is the single thump that follows a premature beat Occasionally the complaint is of a sensation as though the heart were not beating Another common symptom is the feeling of breathlessness or of inability to take a satisfactory breath without any actual dyspnea even on exertion All these subjective symptoms can of course be duplicated in organic disease of the heart as well as in those functional disorders of toxic or reflex nature which cannot be classed among the neuroses in the stricter meaning of that term

1 Pain When actual pain is present its careful analysis will usually show evident differences from true anginal pain Rarely is it referred directly to the retrosternal region Usually its location is in the apical region or over the left half of the precordium Usually too it is made up of twinges of darting pain and the steady boring constricting character of anginal pain is lacking There is seldom any close relationship between the pain and physical effort *Indeed the pain is much more apt to be felt when the patient is sitting quietly or is in bed than when walking* Although the pain of the neuroses is ordinarily easily distinguishable from that seen in serious organic disease it is however by no means always so and it cannot of itself be relied on to make the differential diagnosis between a neurosis and disease of the coronary vessels At times

that either alcohol or tobacco plays any part in the production of the symptoms. Although prolonged emotional strain is the commonest exciting cause, the psychic disturbance is not that of the familiar type of anxiety neurosis and there is, at the beginning at least, no apprehension concerning the state of the heart.

The name "the effort syndrome" was suggested by Lewis, because of the resemblance of the symptoms to those produced by severe muscular effort—rapid heart action, palpitation, throbbing arteries, precordial distress, fatigue, dyspnea on slight exertion, tremor, sweating, etc. Persistent tachycardia and inability to withstand any physical effort are perhaps the most constant symptoms. The heart is never enlarged, although its violent pounding against the chest wall may easily give the impression that it is The heart sounds are sharp and loud and functional systolic murmurs are not uncommon

The *prognosis* varies greatly, depending upon the nature of the exciting cause and the constitutional characteristics of the individual. In the case of most of the incapacitated soldiers, the return to civil life and the resumption of a quiet routine, free from the violent emotional stresses of the war, was followed by a gradual subsidence of the symptoms.

Association of Neuroses with Organic Heart Disease: It is not to be supposed that organic heart disease is found only in individuals with a stable mind and nervous system; when it appears in persons whose mental make-up predisposes them to apprehensions and fears, evidences of this tendency may be found in the appearance of symptoms which cannot reasonably be ascribed to the organic disease present. In such cases, a wide

just what is to be expected in the way of symptoms from the type and grade of the organic lesions present, in order to recognize that certain of the symptoms have no direct relation to the somatic disease.

This association of organic disease with symptoms of a purely neurotic nature is encountered in patients of almost all ages. It is seen in older children with rheumatic heart disease who have been taught, usually by an overanxious mother, that all physical effort is to be avoided; it is found frequently in neurotic women with long-standing but relatively mild mitral stenosis, and it is by no means uncommon in persons in middle life who are oppressed by the knowledge that they suffer from "high blood pressure."

CLINICAL COURSE AND PROGNOSIS

The clinical course and the outcome of a cardiac neurosis depend upon many factors, chief among which are the mental constitution of the individual; the degree of psychic upheaval caused by the cardiac symptoms, and the character of the treatment received. If the symptoms appear in a person of reasonably stable mental composition, and if his anxiety be allayed promptly by wise and tactful management, the cardiac disturbances are immediately stripped of significance and will usually soon disappear. *If, however, the nature of the symptoms be misunderstood and if he be treated as though he had some cardiac weakness, the symptoms tend to become more pronounced and to persist.*

On the other hand, in an individual naturally apprehensive and with a record of earlier psychoneurotic manifestations, even skillful management may do no more than cause a temporary subsidence of the anxiety neurosis and the patient is apt to have from time to time sudden outbreaks of unreasonable fear and panic, even in the absence of definite cardiac symptoms.

DIAGNOSIS

Although there is always the possibility of confusing certain types of cardiac neurosis with such somatic diseases as pulmonary tuberculosis and hyperthyroidism, the chief difficulty in diagnosis lies in distinguishing the neuroses from organic diseases of the heart. In this differentiation a searching investigation into the patient's history, past and present, is of the utmost importance. Evidences of nervous instability, as shown by "nervous breakdowns" in the past and by the tendency to morbid fears

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just what is to be expected in the way of symptoms from the type and grade of the organic lesions present in order to recognize that certain of the symptoms have no direct relation to the somatic disease

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and apprehensions will often be brought to light Frequently the symptoms will be found to have started as the result of the discovery by an insurance examiner of some murmur or cardiac irregularity or as the result of the occurrence of some dramatic case of heart disease in the family of the patient A careful analysis of the symptoms will disclose discrepancies between these and symptoms due to true disease of the heart such as the lack of relationship between the *symptoms and physical* effort and the atypical character and location of the pain Finally a careful examination of the heart itself will fail to reveal any basis for the diagnosis of organic disease The diagnosis of such a neurosis however should never be made merely on the negative findings of the heart *examination While these are essential they are nevertheless only a part* of the evidence upon which the diagnosis should be based *In hardly any condition is there greater need for positiveness and certainty in diagnosis Without confidence himself, the physician can hardly hope to instill confidence into the mind of his patient and such confidence is the basis of all successful treatment*

TREATMENT

In many instances the *problem* is *simple* and a tactful explanation of the situation and reassurance may be all that is needed At other times the therapeutic problem is difficult and complicated and clearly calls for the assistance of a trained and experienced psychiatrist Generally however it falls to the lot of the family physician to deal with such patients *and if he has had the insight to recognize the significance of the emotional* factor he will usually be found to possess the judgment and good sense necessary to effect the cure Tact and common sense will go far toward compensating for the lack of psychiatric technic

A word should be said first concerning *prophylaxis* Obviously the fundamental *difficulty in a patient with a cardiac neurosis lies in his per*sonality and his mental composition and those ingrained characteristics it can hardly be hoped to alter materially But this fact makes it all the more important that as physicians great care should be exercised to avoid supplying such an unstable individual with any suggestion that may serve to crystalize his fluid anxieties and *center them on his heart*

If in the course of health or insurance examinations some unimportant cardiac anomaly is noted by the examiner it is often wise to avoid mention of it or if it seems necessary to apprise the patient of it the

matter should be presented to him in such a way that it will carry with it reassurance and will put his mind at rest concerning its significance Often it is necessary also to caution the anxious parents of children with the milder forms of heart disease concerning the harmful effects of too constant reminders to the child that his heart is crippled and that he is not like other children *Such an attitude may well lead to psychic scars more serious and disabling than those of the heart valves*

Coming now to the matter of treatment usually the first problem to be faced is that of acquainting the patient with the fact that his symptoms are due to emotional causes rather than to disease of the heart itself It might be expected that such knowledge would come to him as a great relief and frequently this is the case But by many patients the intimation that the heart is normal and that the symptoms have a psychic origin is interpreted as meaning that the symptoms are imaginary and the first reaction to such a disclosure is apt to be one of strong resentment Such a reaction must be prevented at any cost for if it occurs the physician s usefulness with that patient is ended In no other condition perhaps is complete faith in the judgment and wisdom of the physician so essential to success in treatment *The patient s understanding of the true character of his complaint must not be gained at the expense of his self respect* If the necessary time and trouble are taken it is usually not difficult to convince the patient that it is realized that his pain palpitation and dyspnea are no less real and disturbing because they are brought about by agencies outside the heart itself the really important difference being only that in his case the symptoms are curable whereas if they were the result of organic heart disease they might not be Such a discussion should of course be preceded by a thorough and complete examination Often it is wise to supplement this by instrumental examinations as well in order that when the statement is made that the heart is not diseased it may be backed up by as powerful an array of facts as possible The casual announcement after a hasty and superficial examination that there is nothing the matter with the heart will almost certainly fail to carry conviction

Frequently before any statement is made concerning the nature of the heart disturbances it is essential to probe deeply into the patient s history from childhood on in order if possible to bring to light evidences of earlier fears and anxieties which have already been proven

groundless Sometimes the patient will be loathe to admit that there has been any conscious element of fear and indeed the emotional reactions may have been chiefly in the deep subconscious strata of his mind Usually however if confidence has been established he will be quite willing to talk freely of his past difficulties and can be made to see the *connection between these and his present symptoms*

If the patient can be persuaded to accept without resentment the idea that his symptoms are of *nervous origin the battle is half won From* that point on the treatment consists chiefly in the liberal application of the two most generally effective remedies in the physician s armamentarium—reassurance and encouragement Chiefly on their skillful use will depend the promptness and completeness of the recovery But the reassurance must not be simply that of the spoken word The patient must be shown how to reassure himself by a demonstration that his cardiac symptoms are made better rather than worse by the exercise and effort which hitherto he may have feared to undertake *To assure a patient that his heart is normal and at the same time to impose various restrictions as to its use is a contradiction which he will be first to recognize*

Exercise of some form is usually an essential part of treatment It serves the double purpose of demonstrating to the patient that his heart is capable of much more than he supposed and of rendering the heart less irritable and less ready to respond to the psychic stimuli The form of exercise to be selected will depend on the special requirements and circumstances of the individual patient In one case it may be some outdoor sport such as golf or even tennis which combines recreation with muscu*lar development In another it may be* graded room-exercise or gymnasium work under the supervision of a trainer Whatever the type of exercise selected it must be carried out regularly and persistently and must of course be graduated carefully to suit the capacity of the patient

As for the use of drugs it is the writer s judgment that they should be avoided unless there is a clear and imperative reason for their administration The encouraging effect on the patient of being told that he does not need medicine usually far outweighs any *transient benefit that may* be gained from its use If at the onset it seems important to utilize the *sedative* action of such drugs as phenobarbital and the bromides these should be discontinued just as soon as the urgent need for them has passed As for drugs such as digitalis and quinidine which are known to

be used for their effects on the heart, they can do nothing but harm. *No intelligent patient can possibly be persuaded that his heart is sound when at the same time he is asked to take digitalis.*

In deciding on the advisability of such measures as rest in bed, baths and massage, the guiding principle should be the probable effect of such procedures on the mind of the patient. The chief objection to them is that they so often serve as a constant reminder to him that he is not well, and this mental effect may nullify any physical benefit that might otherwise be derived from them. Much the same may be said concerning the interdiction of tobacco and coffee. Whenever it is known that the use of either of these substances is excessive and is contributing to the neurotic symptoms, they should of course be forbidden; but when there is no reason to think that the smoking or the coffee drinking plays any part in the production of the symptoms, it is usually wise to permit the continuance of the habit so long as it can be kept within bounds. Every liberty of this sort that can safely be given will have the effect on the patient of encouraging him and of persuading him that he cannot be seriously ill.

From what has been said concerning treatment, it must be apparent that, in the writer's judgment at least, the management of patients with cardiac neuroses belongs essentially to the realm of psychotherapy. The details of such treatment will, of course, vary with the character of the individual patient and with the predilections of the physician. If the latter will but keep in mind the psychic basis of the neurotic symptoms and the need of treating the mind of his patient, rather than the symptoms themselves, and if he can call to his aid a modicum of tact, common sense and optimism, he is likely to be rewarded by results quite as brilliant and as satisfying as are ever obtained in any field of internal medicine.

CHAPTER XI

THE HEART IN ANEMIA

By WILLIAM B PORTER M D

The importance of any given factor in its relation to the heart and its physical and physiological *integrity is immediately divisible into two* issues The first is concerned with the effects of the stress or noxious agent on the normal heart and the second with these effects on the diseased heart or the heart laboring under an abnormal load Hypertension and pregnancy or hyperthyroidism

In 1857 Bamberger[1] reported his observation on patients having chronic anemia and concluded that cardiac enlargement was a frequent result Irvine[2] in 1877 and Barrs[3] in 1891 described in chlorotic individuals the occurrence of bruits which were attributed to cardiac dilatation Hersman[4] in 1893 described murmurs which disappeared with the cure of the anemia and Gautier[5] in 1899 recorded his observations in [illegible] cases of chlorosis and found by percussion cardiac enlargement in [illegible]0 Cabot and Richardson[6] in 1919 found cardiac hypertrophy in patients dying of pernicious anemia in whom no other factor existed to account for the enlargement Ball[7] in 1931 was apparently the first to report a case of severe anemia studied with the aid of a teleoroentgenogram *recording a reduction in heart size with relief of anemia*

Lunde and Schueller[8] in 1910 produced cardiac enlargement in dogs by rendering the animals anemic and Forman and Daniels[9] in 1930 while studying the effects of certain food on anemia in rats observed that the hearts of those animals having low hemoglobin values were considerably larger than the hearts of normal animals When the hemoglobin values fell to 10 Gm the hearts were slightly hypertrophied this became marked as the degree of anemia increased At the very low hemoglobin levels from [illegible] Gm to 3 Gm per 100 cc the hearts weights averaged approximately three times those of normal animals Ellis and Faulkner[10]

in 1939 reported the results from a study of 47 cases with varying degrees of anemia. Twenty of the 38 cases studied by x-ray showed cardiac enlargement, and of the 26 who were followed 18 showed a decrease in heart size with improvement of the hemoglobin level. Ten of the 15 patients studied by electrocardiogram showed abnormal records.

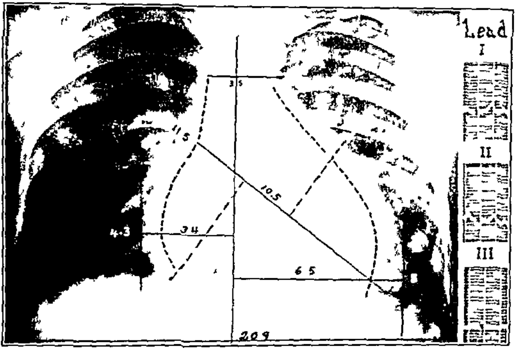

FIGURE 1*

Date	Hemoglobin Gm per 100 cc	Cardiothoracic Ratio Predicted	Transverse Diameter Hodges and Eyster	Actual Transverse Diameter
4 to 18	1 4	58 8 per cent	Data incomplete	12 3 cm
6 to 14	12 7	47 3 per cent		9 9 cm

Electrocardiogram Sinus tachycardia rate 115 otherwise normal

From these reported observations one must conclude that protracted chronic anemias produce significant physical changes in the heart. In 1937 the writer[11] reported the heart changes occurring in hookworm anemia. It was realized that much information was available which dealt with the reaction of man to anemia but the studies were concerned with relatively acute reductions in the oxygen carrying function of the blood, hence, the conclusions were applicable in only a limited degree to the changes developing in individuals with chronic anemia existing over periods of years. Many factors contribute to the physiological adjust

* See footnote p 211

ments occurring in anemia of varying degrees, and duration, and the question was whether or not anatomical changes occur in the heart during the evolution of the compensatory processes

The anemia associated with hookworm disease offered an ideal type of study It varied in intensity, duration and rate of development, and was

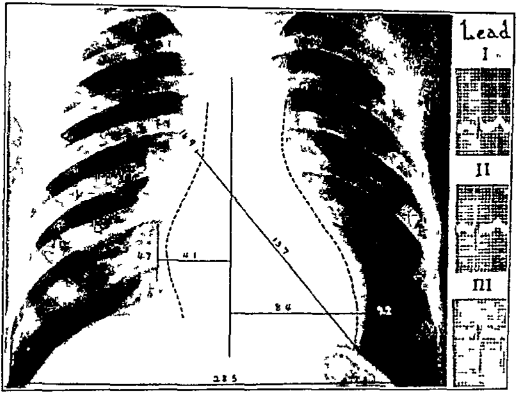

FIGURE 2*

Date	Hemoglobin Gm per 100 cc	Cardiothoracic Ratio Predicted	Transverse Diameter Hodges and Eyster	Actual Transverse Diameter
7 to 10	6 9	49 9 per cent	11.3 cm	13 9 cm
8 to 16	9 5	45 8 per cent	11 4 cm	12 5 cm

Electrocardiogram Sinus rhythm rate 79 electrical axis left preponderance

relievable by medication without the introduction of measures which might confuse the observations In this study an increase in cardiac size occurred in 100 per cent of the patients The data indicated that the changes in heart size were in a few patients due to reducible dilatation (Fig 1), in others to dilatation and hypertrophy (Fig 2), and in a third group to definite hypertrophy unassociated with reducible dilatation (Fig 3)

* See footnote p 211

Cardiac hypertrophy is rightly placed in the category of organic heart disease; hence, one is justified in classing chronic anemia as one of the etiological factors in the causation of this condition. The primary cardiac dilatation may be classed as a physiological adjustment mechanism which disappears when the anemia is relieved; yet if those factors which have

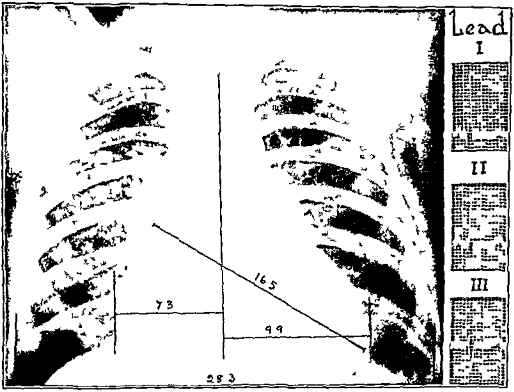

FIGURE 3*

Date	Hemoglobin Gm per 100 cc	Cardiothoracic Ratio Predicted	Transverse Diameter Hodges and Eyster	Actual Transverse Diameter
7 to 3	1.9	60.0 per cent	11.3 cm	17.2 cm

7 to 29 death from intercurrent disease not related to the anemia. Autopsy: Heart weight 630 Gm; otherwise normal.

Electrocardiogram: Sinus rhythm, rate 70; electrical axis left preponderance.

necessitated the dilatation continue, there occurs hypertrophy of the myocardium which is not reducible and is definitely pathological in character.

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* All figures are composed of the first and last teleoroentgenograms; the latter is *indicated* by the dotted line. The outside figures represent the measurements in centimeters of the first and the inside figures of the last teleoroentgenogram. The hemoglobin values were obtained on the same day as the x-ray studies.

The effects of chronic anemia on the diseased heart or the heart under stress of hypertension pregnancy or hyperthyroidism are of major clinical importance The minute volume of blood handled by the heart is increased by anemia and the increase in cardiac output is definitely related to the degree of anemia It is apparent therefore that anemia is an added drain on cardiac reserve in valvular heart disease and hypertension and that it definitely augments the cardiac load of the pregnant woman and the patient with hyperthyroidism This additional work not only augments the degree but definitely accelerates the development of cardiac enlargement and frequently precipitates premature heart failure

Several authors have noted the occurrence of angina pectoris of effort in patients with anemia[12,13,14,15,16,17] The specific nature of the angina syndrome has not been definitely settled but *it is universally* agreed that it is concerned with cardiac work and oxygen supply

When one studies a large number of patients with severe anemias he is impressed by the fact that cardiac pain occurs only in the occasional patient and that the critical level for the anemia is quite variable Practically *all of the reported instances have occurred in patients who are in* the age group to quite logically have degenerated coronary arteries The conclusion reached from a correlation of all the available facts is that the angina syndrome occurs in those anemic patients who have coronary artery disease The degree of anemia necessary to precipitate the angina syndrome varies from case to case depending *upon the physiological* integrity of the coronary arteries and this in turn is dependent upon the degree of coronary artery disease It is doubtful if angina pectoris regardless of the degree of anemia ever occurs in patients with normal coronary arteries yet anemia can precipitate the angina syndrome in patients who have impairment of coronary circulation *though no limitation of cardiac* function be evident when the blood is normal

Case I W M contractor aged 60 First seen September 6 1929 complaining of substernal pain and oppression induced by slight exertion He stated that his first symptoms were noted 14 months previously and *that they were fatigue* slight dyspnea and substernal oppression when he walked rapidly up slight inclines These symptoms had gradually increased in intensity until at this time he could not walk as much as a level city block without experiencing such intense substernal pain and

oppression that he would be forced to rest Rest gave him complete relief

Physical Examination The patient was a well nourished man weighing 196 pounds five feet ten inches in height The mucous membranes and skin were manifestly pale and the tongue was smooth clean and the papillae atrophied The heart was normal in size and shape and there were no cardinal murmurs The first sound was lacking in muscle tone and the second aortic sound was amphoric and ringing in quality Pulse rate 84 sinus rhythm The peripheral arteries and fundus vessels showed *moderate sclerosis The blood pressure was 115 systolic and 85 diastolic The electrocardiogram showed moderate left axis deviation and an isoelectric T wave in Lead I*

Diagnosis (1) *Angina pectoris* (2) *coronary sclerosis* (3) *pernicious anemia*

Course and Treatment

September 7—Hemoglobin 62 per cent RBC 2 130 000

September 8—*Liver therapy begun*

September 20—Hemoglobin 76 per cent RBC 3 200 000 On *this date he could walk on the level with comfort*

October 10—Hemoglobin 86 per cent RBC 4 400 000 No *symptoms with average physical activity*

November 2—Hemoglobin 94 per cent RBC 5 120 000 No *symptoms and actively engaged in his vocation*

This patient was followed *for three years There was a consistent recurrence of symptoms when the blood levels reached hemoglobin* 70± and RBC 3 000 000± He died in 1933 Cause of death Acute coronary occlusion

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the exception of the portal system. The commonest site of origin, however, is in the veins of the pelvis and of the lower extremities, where thrombi are prone to form in post partum and postoperative patients or in patients with phlebitis. Less frequently emboli may arise from vegetations on the valves of the right heart or from mural thrombi originating in the right auricle. Coronary occlusion may be complicated by pulmonary embolism when mural thrombi are dislodged from the endocardium overlying infarcted areas in the right ventricle. Of these various conditions in which embolism may arise, the most important from the standpoint of frequency and possible confusion in diagnosis is the postoperative group. In this group embolism is most likely to occur in indi-

CHAPTER XII

THE HEART IN PULMONARY DISEASE

By Thomas M. Durant, M.D.

Introduction: Pulmonary disease is occasionally responsible for serious disturbances in cardiac function. When such a relationship between lung disease and the heart exists, the condition has been designated *pulmonary heart disease* or *cor pulmonale.* The types of pulmonary disease which may thus implicate the heart may be conveniently divided into two groups, acute and chronic. The acute group consists of cases in which sudden obstruction in the pulmonary arterial tree by embolism leads to dilatation of the right ventricle. The chronic group is made up of cases in which diffuse, bilateral parenchymal disease of the lungs produces widespread obliteration of capillaries in the alveolar walls, and serious intrapulmonary resistance to blood flow. The right ventricle becomes hypertrophied, and eventually incompetent, resulting in congestive failure. There are also to be included in the chronic group rare cases in which primary pulmonary arteriosclerosis produces a similar cardiac effect. There is a close analogy between the production of right ventricular strain in these cases, and the production of left ventricular strain in cases of systemic hypertension. In fact, the term *pulmonary hypertension* is commonly used in connection with cases of pulmonary heart disease, even though measurement of the pressure in the lesser circulation is not possible by clinical methods

ACUTE PULMONARY HEART DISEASE

Etiology: The syndrome to be designated by the term *acute pulmonary heart disease* or *acute cor pulmonale* has been attributed to sudden dilatation of the right ventricle and pulmonary artery, produced by embolic blockage of the lesser circulation. The emboli which produce this effect may arise in any part of the systemic venous circulation, with

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the exception of the portal system. The commonest site of origin, however, is in the veins of the pelvis, and of the lower extremities, where thrombi are prone to form in post partum and postoperative patients, or in patients with phlebitis. Less frequently, emboli may arise from vegetations on the valves of the right heart, or from mural thrombi originating in the right auricle. Coronary occlusion may be complicated by pulmonary embolism when mural thrombi are dislodged from the endocardium overlying infarcted areas in the right ventricle. Of these various conditions in which embolism may arise, the most important from the *standpoint of frequency and possible confusion in diagnosis* is the postoperative group. In this group embolism is most likely to occur in individuals over 40 years of age.

Not all pulmonary emboli produce the cardiac effect known as the acute cor pulmonale. Very small emboli do not do so, and, on the other hand, extremely large ones cause death before this effect is apparent. Between the two extremes, however, there is a considerable group of cases in which the acute cor pulmonale is an important feature. It seems probable, as suggested by Barnes, that reflex spasm of some or all of the pulmonary arteries at the hilum markedly enhances the degree of circulatory obstruction caused by the embolus itself in these cases. Furthermore, there is convincing experimental evidence that a pulmono cardiac reflex exists in association with pulmonary embolism which induces significant coronary vasoconstriction. The *reduction in blood supply to* the heart muscle which results from this vasoconstriction undoubtedly *contributes considerably to the difficulties* under which the right ventricle is already laboring as it attempts to overcome the obstruction in the pulmonary circulation.

The studies of Fineberg and Wiggers have added much to our knowledge of the circulatory alterations and changes in right ventricular function which occur when there is obstruction in the pulmonary circulation comparable to that which exists in pulmonary embolism. They have found that the right ventricle of the dog is able to compensate for compression of the pulmonary artery up to approximately 58 per cent of its total caliber, being able under such circumstances to overcome the added resistance and supply the left ventricle with a normal amount of blood. One factor shown to be of utmost *importance in this compensation* for added resistance is the increased initial tension and diastolic stretch of the

right ventricle Greater degrees of compression of the pulmonary artery overwhelm the compensatory mechanism and there result a diminished transfer of blood to the left ventricle a lowered aortic pressure and a diminished coronary blood flow The lowered blood supply to the myocardium undoubtedly plays an important role in the eventual complete failure of the right ventricle Two deductions of therapeutic importance are made from these findings The first concerns venesection which is to be condemned on the ground that lowering of venous pressure reduces the initial tension within the right ventricular cavity the factor shown to be of such importance in the maintenance of normal blood flow to the left ventricle The second concerns the importance of attempting to maintain an adequate arterial pressure and coronary flow to aid the right ventricle

Clinical Features The symptoms and signs of acute pulmonary heart disease will be considered along with those of the pulmonary embolism causing it but special emphasis will be placed on the cardiac features The size of the embolic occlusion determines to a large extent the character and severity of the symptoms and signs When the embolus is very large and obstructs a main branch of the pulmonary artery sudden death may be the consequence This tragedy may occur entirely without warning in a patient whose postoperative course has been apparently uneventful Less severe cases experience sudden intense dyspnea and thoracic oppression or definite substernal pain Nausea and vomiting may occur There is noted a sharp drop in blood pressure a rapid thready pulse ashy pallor and profuse cold perspiration evidences of peripheral circulatory collapse Within the first hour or two if death is averted the manifestations of shock begin to abate and the signs of right heart strain which constitute the acute pulmonary heart disease syndrome become apparent The right ventricle has dilated and the conus region may impinge on the anterior chest wall resulting in systolic pulsation in the pulmonary area This impingement may also cause a friction rub along the left sternal border in the second and third intercostal spaces The increased blood pressure within the pulmonary circulation is reflected in forceful closure of the pulmonary valve and thus is made evident to the examiner by accentuation of the pulmonary second sound The neck veins show distention thus manifesting the rise in systemic venous pressure which occurs behind the dilated right ventricle Marked

pulsation in the systemic veins indicates relative tricuspid insufficiency Cyanosis which may not have been evident during the shock phase is often now quite apparent In this stage the outcome may still be unfavorable due to progressive failure of the right ventricle or there may be gradual improvement with restitution of right ventricular function to normal

One or two days after the occurrence of the embolic accident evidence of the lung involvement (infarction) may become apparent Cough is often present and may be productive of bloody sputum Limitation of expansion on the involved side of the chest dullness to percussion diminished breath sounds or occasionally bronchial breathing and a pleural friction rub over the infarcted area may be noted It should be emphasized however *that no pulmonary signs may be made out at any time in* some cases and hemoptysis is often entirely absent Fever and leukocytosis are characteristically present within 12 to 24 hours after onset

When small emboli reach the lungs the acute cardiovascular syndrome described as constituting the acute cor pulmonale may be either entirely absent or very mild In these cases the diagnosis often is not made clinically or is suspected only when pulmonary signs or pleural pain appear

Roentgenologic evidence of pulmonary infarction is usually lacking in the early stages The triangular or wedge shaped radiopacity classically associated with this condition is seen infrequently even in the later stages The usual late findings is a shadow which has no pathognomonic characteristics (K Shirley Smith)

The *electrocardiographic changes* associated with pulmonary embolism constitute one of the extremely interesting aspects of the acute cor pulmonale The characteristics of the changes observed and their rapid regression to normal in nonfatal cases have been summarized by Durant Ginsburg and Roesler as follows

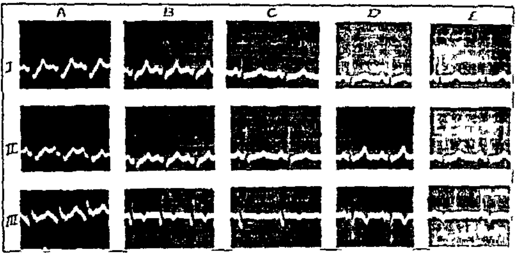
Early changes (Usually present for only a few hours after onset but occasionally persisting 12 to 24 hours)

1 Intraventricular block of the right bundle branch type with broad shallow S waves in Leads I and II

2 Marked depression of the S T segment in Leads I and II may be present (Love Brugler and Winslow)

Later changes:

1. Reëstablishment of normal intraventricular conduction time, associated with the supplanting of the broad S wave in Leads I and II by a wave of sharp, narrow contour.
2. A sloping ascent of the S T segment in Leads I and II
3. A large Q wave and inverted T wave in Lead III



Electrocardiographic abnormalities of the type described above as early changes have been produced experimentally by the author by means of large air injections into the systemic venous circulation of dogs Their onset coincides with the sudden development of right heart dilatation in these animals *It is suggested that these changes are those of acute right heart dilatation whatever be the mechanism responsible for its development*

Diagnosis The clinical features associated with the acute cor pulmonale of pulmonary embolism closely resemble those observed in typical cases of coronary occlusion This similarity in these two conditions may lead to considerable difficulty in their differentiation particularly in middle aged or elderly postoperative patients The postoperative period may be complicated by either of these disasters in the later decades of life Both in the acute cor pulmonale and in coronary occlusion there may occur a sudden onset with dyspnea substernal pain nausea and vomiting and the manifestations of vascular collapse The friction rub associated with the dilated pulmonary conus of the former condition may readily be mistaken for that heard in infarction of the anterior cardiac wall in the latter Fever and leukocytosis are present in both Added to the difficulty of differentiation is the fact that the symptoms and signs long considered characteristic of pulmonary embolism (hemoptysis pleural friction rub and the signs of pulmonary consolidation) are often absent in its earlier stages and sometimes also in its later stages

This diagnostic problem has stimulated investigation of electrocardiographic variations as a means of differentiation It has been found that while both the acute cor pulmonale and coronary occlusion produce serial electrocardiographic changes *the rapidity with which these changes regress is much greater in the former than in the latter* Furthermore the pattern of the changes is different in most instances particularly when electrocardiograms taken within an hour or two of the onset of symptoms are available for comparison with later curves

Treatment The prevention of thrombus formation in the veins of the legs and pelvis and hence indirectly the prevention of pulmonary embolism is obviously the ideal in treatment Several regimes have been devised to effect this result in postoperative and post partum patients and encouraging results have been reported The reader is referred to articles by Barnes and by Robertson for further details Reference should also be

made to the studies of Murray and Best and their coworkers concerning the anticoagulant action of heparin. They have demonstrated that this substance, when highly purified and well diluted in saline solution may be safely injected intravenously. In animals it is effective in the prevention of thrombosis of veins produced by various means. In the human it has been administered postoperatively but a final opinion concerning its effectiveness in the prevention of thrombosis cannot be had until a very large series of cases has been studied. It is to be hoped that this method will fulfill the expectations based on the results of these preliminary investigations.

In the treatment of the attack itself the administration of papaverine hydrochloride or of eupaverine is to be recommended as the most valuable remedy available at present. These drugs are injected slowly by the intravenous route in dosage of 0.03 Gm (½ grain) and 0.065 Gm (1 grain) respectively. The injection may be repeated at hourly intervals. The beneficial results which have been obtained with this therapy may be attributed in all probability to relaxation of spasm in the pulmonary arteries and possibly also to coronary dilatation. Morphine or pantopon hypodermically in dosage of 0.016 Gm (¼ grain) and 0.02? Gm (1/3 grain), respectively may be used in conjunction with this medication for more adequate relief of pain. Oxygen administration is effective in some cases in relieving dyspnea, cyanosis and anxiety and its routine use is to be recommended. The administration of 100 per cent oxygen by the newly devised Mayo clinic technic (Boothby, Mayo and Lovelace) is more effective and less costly than the older methods of oxygen therapy. The use of atropine 0.001–0.002 Gm (1/60 to 1/30 grain) subcutaneously is indicated as a means of minimizing vagal reflexes which have an adverse effect on coronary blood flow. Recommended by some venesection is to be condemned on the basis of the studies of Fineberg and Wiggers (see Etiology). Embolectomy (Trendelenburg operation) has been attempted with success in rare instances.

CHRONIC PULMONARY HEART DISEASE

Incidence. *Serious disturbances of cardiac function secondary to chronic pulmonary disease are relatively uncommon. Morbidity statistics from various parts of the United States indicate an incidence varying from as little as 0.5 per cent of all cases of heart disease to as much as*

5.8 per cent. The latter, high figure is based on the study of 1000 cases in the Chicago area (Maher, Sittler and Elliot), but includes 41 cases (4.1 per cent) in which extrapulmonary factors also were involved in the cardiac condition.

Etiology: Originally the terms "Emphysema heart" and "Chronic pulmonary heart disease" were used synonymously. At the present time, however, the etiology of this group of cases is recognized as being varied, and made up of all diseases which produce chronic pulmonary hypertension and thus lead to right ventricular strain. The various diseases which belong in this category will be considered separately.

Pulmonary Emphysema: The commonest cause of chronic pulmonary heart disease is pulmonary emphysema. Isaakson in 1871 demonstrated the widespread narrowing, with subsequent thrombosis, rupture, and atrophy, of the pulmonary capillaries in emphysema. This anatomical disturbance is now well recognized as the basis for the development, in sequence, of pulmonary hypertension, right ventricular hypertrophy, and finally, right ventricular dilatation and failure in advanced cases. In a recent post-mortem study, Griggs, Coggin and Evans found right ventricular hypertrophy in 28.9 per cent, and definite congestive failure in 22.3 per cent of 45 uncomplicated cases of emphysema.

Pulmonary Tuberculosis: Careful roentgenological and post-mortem studies have demonstrated conclusively that right ventricular hypertrophy may occur as a result of tuberculous pulmonary disease. There is no agreement, however, as to the frequency with which such involvement of the heart does occur. Nemet and Rosenblatt reported exclusive hypertrophy of the right ventricle in 33.8 per cent of 71 post-mortem cases. On the other hand, Griggs, Coggin, and Evans found only 3.7 per cent pure right ventricular hypertrophy in 1470 cases of tuberculosis uncomplicated by other pulmonary disease. The latter figure, based as it is on a large series of cases, must be considered the more accurate, and is in better accord with the general opinion on this subject.

Congestive failure supervenes in occasional cases of pulmonary tuberculosis. In the post-mortem studies of Griggs, Coggin and Evans, previously mentioned, 1.8 per cent had definite congestive failure. No statement is made as to the relationship of such a serious cardiac sequel to the degree of tuberculous pulmonary involvement. In the author's

experience it is only in cases of advanced bilateral disease that right heart failure occurs The roentgenogram and electrocardiograms from an illustrative case are reproduced in figure 2

Nontuberculous Pulmonary Fibrosis Diffuse bilateral fibrosis of the lungs due to chronic nontuberculous infection (*e g*, bronchiectasis), or

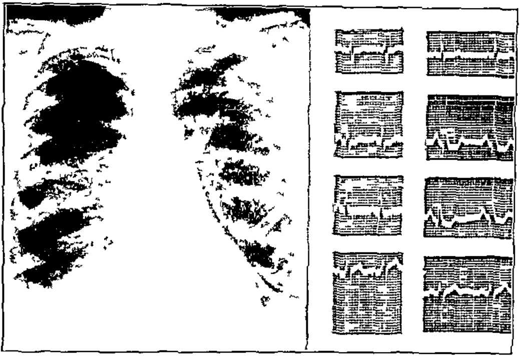


FIGURE 2 Chest x ray and electrocardiograms of a 63 year-old male with pulmonary tuberculosis and right heart failure The x ray demonstrates the bilateral fibroid tuberculous lesion with spontaneous pneumothorax or large cavity at the right apex Sputum positive for tubercle bacilli The first electrocardiogram was taken at a time when cardiac failure was severe and shows right axis deviation without P wave changes Treatment consisted in a period of complete bed rest digitalization oxygen inhalation and diuretics and resulted in a complete disappearance of the signs of failure The second electrocardiogram was taken seven months later and shows a normal axis but abnormally tall broad P waves in Leads II and III The changes in the S T segment are the result of digitalis administration The improvement resulting from treatment in this case has been maintained up to the present one year after the second electrocardiogram (Temple University Hospital case)

to inhalation of silica laden dust, may produce cardiac involvement in the same manner as in tuberculous infection The pneumoconiosis group is of sufficient importance to warrant separate consideration

Pneumoconiosis This form of pulmonary fibrosis, which is such an important industrial hazard, is frequently the cause of pulmonary heart disease in mining regions where anthracosilicosis rather than pure silicosis, occurs (Dyson) Pure silicosis leads to early disability and death

from silicotuberculosis, thus allowing insufficient time for the development of cardiac manifestations A valuable statistical study of this subject is that of Coggin, Griggs and Stilson, who found right ventricular hypertrophy to be present in approximately one half of 102 autopsy cases of pneumoconoiosis Definite congestive failure was more frequent in these cases (51 per cent) than was tuberculosis (40 per cent) The conclusion

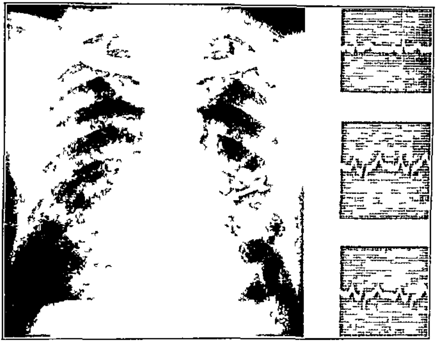


FIGURE 3 Chest x ray and electrocardiogram of a 58 year old male with advanced anthracosilicosis and chronic pulmonary heart disease Enlarged pulmonary conus indicated on x ray by arrow Electrocardiogram shows normal axis with large broad P waves in Leads II and III Tests of circulatory function in this case indicated incipient right heart failure Death resulted however not from congestive failure but from acute miliary tuberculosis which developed a few weeks after the above x ray was taken (Temple University Hospital case)

is reached from these studies that if pneumoconiosis is uncomplicated by tuberculosis or other pulmonary infection death from cardiac *failure is* to be expected in a considerable percentage of cases

Figure 3 illustrates evidence of chronic pulmonary heart disease by roentgenogram and electrocardiogram in a case of anthracosilicosis

Bronchial Asthma Bronchial asthma, when long standing and severe, leads to definite right ventricular hypertrophy MacDonald reported eight fatal cases in which post mortem examination verified this fact However, congestive failure secondary to bronchial asthma is rare Alex

ander, Kountz, and Luten have suggested that the heart may be protected during an attack of asthma by the increased intrathoracic pressure which results in a reduced return of venous blood to the heart and a reduction in the work required of the heart.

Mediastinal Distortion: Drastic displacement of the mediastinal structures to right or left, often associated with rotation of the heart on its longitudinal axis, may result in cardiac embarrassment. Conditions which may cause such extreme displacement include. Fibroid tuberculosis; non tuberculous infections leading to pulmonary sclerosis, neoplasms, and deformities of the spine or chest wall It is difficult in these cases to distinguish between symptoms due to the primary condition responsible for the displacement, and those due to the displacement itself. That tachycardia may be due alone to displacement has been pointed out by Hedblom, who showed that it may persist even though the pulmonary disease be inactive, and that it is relieved directly following thoracoplasty

Rheumatic Pneumonitis: Patients who have suffered from long standing rheumatic infection frequently present, in addition to chronic damage of the heart valves, an interstitial pneumonitis with hyperplasia of elastic tissue. Previously it was assumed that this change in the lungs was a result of long-standing pulmonary congestion due to mitral stenosis The studies of Gouley have shown, however, that, while congestion intensifies the fibrosis in the lungs, it is only a secondary factor in the production of fibrotic changes. Primarily involved is a chronic rheumatic interstitial pneumonitis, which, like rheumatic myocarditis, is often accompanied by evidence of recurrent inflammation The right heart failure which characteristically terminates rheumatic heart disease may then result, at least in part, from fibrotic pulmonary disease, with its resultant increased capillary resistance to blood flow, rather than from mitral valvular disease. Gouley has shown that such failure may occur even in the absence of significant mitral valvular dysfunction Such cases as these could be correctly classified, then, as examples of pulmonary heart disease of rheumatic origin.

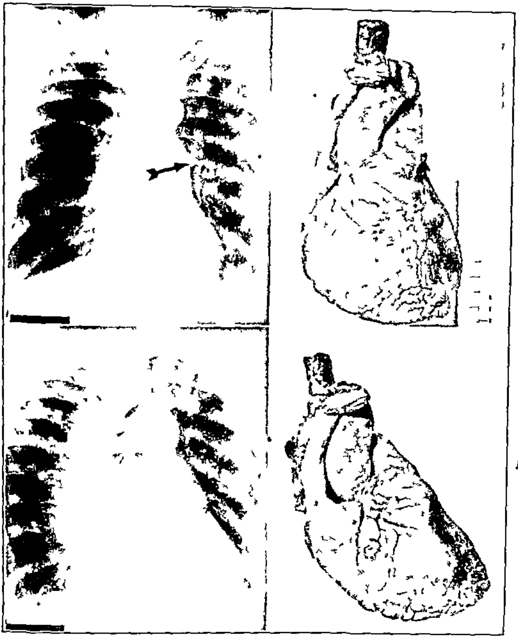
Pulmonary Arteriosclerosis: Cases in which sclerosis of the pulmonary circulation is of clinical significance are rare, even though some degree of pulmonary sclerosis is found almost constantly at autopsy (Brenner). Those instances in which right ventricular enlargement and failure do occur as a result of primary pulmonary vascular disease are mainly cases

of diffuse arteriolar sclerosis Kaump and Dry *recently reported 13 such* cases in 11 of which there was right ventricular hypertrophy of a degree comparable to the severity of the sclerosis Seven of these showed a strikingly uniform clinical picture and terminated in a dramatic type of congestive failure with cyanosis and entire lack of response to treatment The use of the term Ayerza s disease as applying to these cases has fallen into disrepute because it is a nondescriptive term and because there is no general agreement as to what it signifies

Syphilis of the Pulmonary Arteries This is an extremely rare condition Brenner reports that there are only 14 cases in the literature in which the diagnosis is reasonably well proven

Clinical Features The symptoms and signs of chronic pulmonary heart disease are first those associated with the primary pulmonary disease and second those produced by the secondary cardiac dysfunction The pulmonary symptoms and signs need not be discussed in this chapter since such a discussion would be beyond the scope of this book but it should be emphasized that dyspnea due entirely to the primary pulmonary *disease is very commonly encountered The presence of this* symptom then does not necessarily indicate cardiac failure as it so often does in other forms of heart disease Cyanosis likewise may be due entirely to lung pathology though it is frequently aggravated when cardiac failure occurs

Two stages may be recognized in the development of the pulmonary heart disease syndrome The first is that during which right ventricular hypertrophy is developing as a response to pulmonary hypertension but during which maintenance of circulatory efficiency persists At this time there is seldom any evidence of cardiac involvement which can be detected apart from roentgenologic and electrocardiographic study There are no symptoms other than those which can be accounted for by the lung disease and on physical examination accentuation of the pulmonary second sound due to pulmonary hypertension may be the only cardiac finding The roentgenologic and electrocardiographic abnormalities which have *made possible a recognition of the disease process in* this stage will be discussed later Patients generally remain in this state of compensated heart disease for a considerable period of time often years before passing gradually into the second stage



A

B

FIGURE 4 *A* *Pulmonary emphysema with chronic pulmonary heart disease in a male* aged 66 Dyspnea and productive cough for five years Congestive failure for two weeks prior to first admission to hospital Marked improvement on rest digitalization diuretics and oxygen inhalation Second attack of congestive failure six months later resulting in death in spite of treatment The roentgenogram taken in the routine posteroanterior *position shows the contour of the heart* to be that of enlargement of the outflow tract of the right ventricle The convexity of the left middle border (arrow) represents enlargement of the pulmonary artery as is well shown by the post mortem specimen from this case photographed in a position corresponding to that of the heart in the roentgenogram *B* Same case as in Fig 4 *A* Roentgenogram and post mortem specimen in the right *anterior oblique position* The convexity of the midventral portion of the cardiac silhouette is seen to be formed by the pulmonary artery in its upper portion and by the pulmonary conus in the lower (*Temple University Hospital case*)

In the second stage, that of right heart failure, the well-known manifestations of decompensation of the right ventricle appear. These include: Increased venous pressure; enlargement of the liver, edema of the dependent parts, albuminuria, and other evidence of renal congestion in the urine, and, in advanced cases, ascites and hydrothorax. Enlargement of the heart may be detected on physical examination, although this is often very difficult in the presence of emphysema or other advanced pulmonary disease Auricular fibrillation is seldom present, in contrast to its frequent occurrence in rheumatic and arteriosclerotic heart disease Gallop rhythm may be heard along the left sternal border. Its presence indicates that the prognosis is very poor. In cases which have reached an advanced stage of cardiac failure the course is often a progressive one in spite of treatment.

Roentgenologic examination of the chest is of paramount importance in pulmonary heart disease In the first place, this study will yield important information concerning the character of the pulmonary disease present. In the second place, a careful examination of the heart contour will usually give evidence of cardiac involvement, when such is present, by demonstrating enlargement of the outflow tract of the right ventricle (Kirch, Assmann). The latter is an important early indication that pulmonary hypertension exists, and may be recognized when the normal concavity of the left border of the cardiac silhouette is replaced by a bulging convexity representing enlargement of the pulmonary artery and conus (Figures 3 and 4 *A* and *B*). This bulging convexity is usually more marked in the right anterior oblique position than in the antero-posterior. When there is uncertainty as to the status of the right ventricular outflow tract in the conventional roentgen examination, accurate measurement of the individual chambers of the heart and of the thoracic blood vessels may be achieved by the method of Robb and Steinberg This method consists in the rapid intravenous injection of 70 per cent diodrast, followed by the taking of roentgenograms at short intervals to visualize the passage of the dye through cardiac chambers and thoracic blood vessels This method has greatly extended the value of roentgenology in the diagnosis of early chronic pulmonary heart disease.

In the later stages of chronic pulmonary heart disease enlargement of the body of the right ventricle is added to the earlier outflow tract enlargement, and there will be noted at this time a prominence of the

right ventricular contour in the left anterior oblique position Enlargement of the right auricle is seen infrequently There is usually no increase in the transverse diameter of the heart a fact worthy of considerable emphasis since this measurement is so often relied upon as an index of cardiac size

Mitral stenosis and certain forms of congenital heart disease (notably pulmonary stenosis and patent ductus arteriosus) are important causes of enlargement in the right ventricular outflow tract and must therefore be differentiated from pulmonary heart disease In mitral stenosis there will be evidence of left auricular enlargement demonstrable in the lateral projection with a barium filled esophagus Left auricular enlargement is only rarely observed in pulmonary heart disease Congenital abnormalities may usually be differentiated by the history and physical findings

A sign frequently observed fluoroscopically in cases of advanced pulmonary emphysema or fibrosis is inspiratory distention followed by expiratory diminution of the cardiac silhouette more marked on the right side than on the left (Roesler) This sign is a manifestation of marked diminution in lung tissue elasticity When lung function is so *impaired the pulmonary tissue cannot rapidly adjust itself to changes* in the volume of the thorax The respiratory movements of the chest wall are thus transmitted to the heart Whether or not this effect plays any significant role in the eventual development of heart failure is not known

The *electrocardiogram may or may not prove of diagnostic value in* cases suspected of having chronic pulmonary heart disease When definite right axis deviation is present and is not accounted for by the presence of mitral stenosis or congenital heart disease it is of considerable value However in many cases of chronic cor pulmonale a normal axis or even left axis *deviation* may be found This is particularly true in cases of emphysema with coexisting *hypertension of the greater circulation*

Abnormalities of the P wave are found in some cases and when present are of diagnostic importance These changes consist in increased height and breadth of the P waves in Leads II and III (Figs 2 and 3) *Notching is rarely seen* During periods of congestive failure the enlargement of these waves may *disappear reappearing with return of compensation* (Fig 2) The P wave enlargement so commonly seen in cases of mitral stenosis is usually most marked in Leads I and II and

conspicuous notching is frequently present. In congenital pulmonary stenosis increased height of the P waves is not associated with increased width.

Studies of the Circulatory Function: Various tests of circulatory function are of diagnostic value in many cases of pulmonary disease. Oppenheimer and Hitzig have extensively investigated this subject. They have shown that, in uncomplicated pulmonary disease these tests are normal This is also true even in the early stages of pulmonary heart disease when right ventricular enlargement is present, but in which decompensation has not occurred. *The presence of abnormal circulatory measurements indicates that pulmonary insufficiency is complicated by myocardial insufficiency.* The myocardial failure may be incipient or frank isolated failure of the right heart resulting from the pulmonary disease, or it may be due to unrelated, coexisting cardiovascular disorders which produce either left ventricular or universal heart failure. Incipient right heart failure is characterized by the presence of a normal initial venous pressure and a varying rise in this pressure during compression of the right upper quadrant of the abdomen. The arm to lung circulation time (ether time) may or may not be prolonged, and the lung-to-tongue time (saccharin time minus ether time) is normal. In frank isolated right heart failure there is a high initial venous pressure, a considerable rise in pressure on right upper quadrant compression, a prolonged arm-to-lung time, and a relatively normal lung to tongue time. Left heart failure (due to coexisting cardiovascular disease, such as hypertension or coronary disease) is characterized by a normal initial venous pressure, with or without a rise on right upper quadrant compression, and a considerably prolonged lung to tongue time. Universal heart failure, secondary to disease of the left heart, and possibly to pulmonary disease in addition, combines these features of left and right heart failure.

Diagnosis: The following criteria should be established before making a diagnosis of chronic pulmonary heart disease: (1) The presence of pulmonary disease of a type which may be responsible for hypertension of the lesser circulation, and, (2) evidence by roentgenogram or electrocardiogram of right heart hypertrophy, not explained by the presence of mitral valve disease or congenital cardiac abnormality. Right ventricular failure in a patient presenting these qualifications is further

evidence in favor of such a diagnosis, but need not be present. Circulatory measurements may indicate incipient right heart failure in the absence of other findings usually relied upon for a diagnosis of myocardial insufficiency. These measurements may also aid in differentiating cases of pulmonary heart disease and those of pulmonary disease in which there is a coexisting cardiac condition of a type unrelated to the lung pathology.

Treatment: Consideration must be given both to the proper management of the primary pulmonary disease, and to the manifestations of cardiac failure when these appear. The former is of extreme importance in the prevention of the latter, but its consideration would be extraneous to the scope of this volume.

Treatment of cardiac failure complicating pulmonary disease consists in the judicious use of those measures universally employed in myocardial insufficiency, regardless of etiology, namely: Rest; digitalis, and diuretics Digitalis is frequently of value in alleviating symptoms in the earlier stages of failure, but the effects to be expected are not as dramatic as those often produced by it in left ventricular failure. Diuretics are indicated when frank right-sided failure has occurred. *Special mention should be made of the value of oxygen administration,* a method of treatment emphasized by Barach. Cases of pulmonary disease of sufficient severity to cause cardiac embarrassment show either a diminished oxygen saturation of arterial blood, or normal oxygen levels maintained at the expense of increased ventilation. Continuous administration of an oxygen-enriched atmosphere to these patients relieves dyspnea and reduces pulmonary ventilation in most instances. Intermittent oxygen therapy may be used several times daily over long periods of time with considerable success in alleviation of symptoms and in prolonging life. Relief of myocardial anoxemia may well be an important factor in the improvement experienced by cases so treated.

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CHAPTER XIII

THE CARDIOVASCULAR SYSTEM WITH RELATION TO THE KIDNEYS

By J. M. Hayman, Jr., M.D.

Introduction: While the function of every organ in the body is dependent on an adequate blood supply, the relation between the cardio vascular system and the kidneys is particularly intimate. Bier expressed this in saying, "The heart and kidneys together secrete the urine." The relation is a reciprocal one. Inefficiency of the heart, with diminished blood flow or inadequate blood pressure leads not only to a decreased urinary output, but to the appearance of abnormal constituents such as albumin in the urine. Primary kidney disease of certain types on the other hand leads to an elevation in blood pressure and all the train of events in the cardiovascular system included under the term "hypertensive heart disease."

While the processes involved in the formation of urine in the kidney are extremely complex, physiologists are now pretty generally agreed on the fundamental importance of two mechanisms, glomerular filtration and tubular reabsorption. As blood flows through the glomerular capillaries, there is separated from it, by a purely physical process, a protein free *ultrafiltrate of plasma, containing all the dissolved substances present* in plasma. Except for minor differences in the concentration of certain electrolytes due to the impermeability of the normal glomerular membrane to protein, and which is spoken of as the "Donnan effect," these dissolved substances are present in the glomerular filtrate in the same concentration at which they exist in plasma As this glomerular filtrate passes down the renal tubule, it is modified by the active reabsorption of water, glucose, sodium, chloride, etc., by the tubule cells and the diffusion of a certain amount of waste products, such as urea, which have been concentrated in the lumen of the tubule by the reabsorption of

water, back from tubular lumen into peritubular capillaries In addition to these two processes of glomerular filtration and tubular reabsorption, there is convincing evidence that at least certain foreign substances as phenolsulfonphthalein, diodrast, and hippuran are transferred from the peritubular capillaries to the lumen of the tubule by secretion [1]

In order that there may be filtration in the glomeruli, there must first of all be an adequate blood pressure in the glomerular capillaries to overcome the osmotic pressure of the plasma proteins and to drive the filtrate through the tubule In the frog glomerular capillary pressure averaged 51 per cent of systolic aortic pressure [2] in the isolated perfused mammalian kidney Winton[3] estimated the glomerular pressure as two thirds of the mean aortic pressure Applying these experimental results to man would indicate that with a mean aortic pressure of 110 mm Hg glomerular capillary pressure would be about 60 or 70 mm Hg The colloid osmotic pressure in man averages about 25 mm Hg, leaving a filtration pressure of 35 or 45 mm Hg Urine formation must of necessity stop when systolic aortic pressure falls to 50 mm Hg as a matter of fact however, it usually ceases when systolic pressure has fallen to about 75 mm Hg or even higher figures in patients with hypertension and marked sclerosis of the smaller renal arterioles Systolic blood pressures of 75 to 80 are not infrequently encountered in severe coronary occlusion as well as in surgical shock and Addison s disease It is obvious that under such circumstances little or no excretion of urine will occur, and that attempts to produce diuresis by drugs which act on the kidney are bound to fail Attention must be directed toward improvement of the circulation and elevation of blood pressure If this is accomplished urine excretion will take care of itself When these low blood pressures have lasted for some hours or days there will of course, be retention of waste products in the body with elevation of blood urea nitrogen etc

It was stated above that the normal glomerular membrane is impermeable to the plasma proteins and that the glomerular filtrate is protein free If however, blood flow and consequently oxygen supply to a glomerulus is reduced the permeability of the membrane is increased so that it leaks protein Hermann[4] demonstrated years ago (1862) that transient albuminuria followed temporary compression of the renal artery Subsequent work has shown that the glomerulus is the structure in which the escape of protein in this condition takes place Starr[5]

showed that transient albuminuria followed renal vasoconstriction produced by a variety of means such as infusion of adrenalin inhalation of CO_2 ephedrin or fright These observations were explained by the conception that renal vasoconstriction causes increase in the duration and extent of the normal intermittent interruptions in the glomerular circulation Permeability of the glomerular membranes is so increased by these lengthened interruptions that when blood flow is reestablished albumin escapes This conception may apply to those albuminurias in man which result from severe muscular exercise or from emotion or which are produced reflexly It may explain the occurence of albuminuria in the urine of normal people

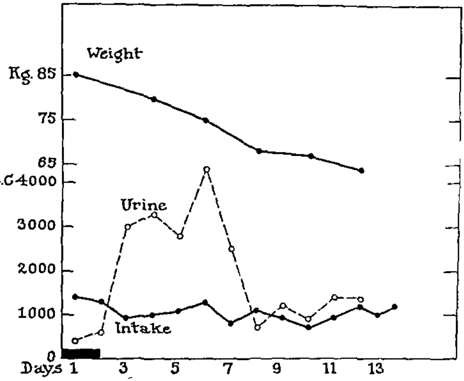
CONGESTIVE HEART FAILURE

The most marked albuminurias from partial asphyxia of the glomerular membrane probably occur in congestive heart failure Here there is an increase in venous pressure and a diminished cardiac output both of which decrease the rate and volume of blood flowing through the kidneys The urine output in congestive heart failure is usually reduced in proportion to the degree of failure The specific gravity is high and the urine contains a considerable amount of protein hyaline and granular casts and not infrequently an abnormal number of red blood cells Kidney function as measured by the excretion of phenolsulfonphthalein or clearance tests is reduced When the urine volume is reduced to a point where for a given specific gravity it is too small to contain all the waste that must be eliminated per day nitrogen as urea and creatinine and other substances accumulate in the blood

The degree of nitrogen retention may be surprisingly great figures that are usually considered indicative of uremia being not infrequently encountered However nonprotein nitrogen values above 100 usually are indicative of some preexisting kidney disease or a purely renal complication All these evidences of kidney disease improve or disappear with the restoration of cardiac compensation These abnormal findings should not be taken as justifying a diagnosis of cardiorenal disease They are simply the result of inadequate renal blood flow Of course a patient may have organic kidney disease either glomerulonephritis or nephrosclerosis in addition to cardiac failure But I know of no way to estimate the degree of such preexisting kidney insufficiency in the pres

ence of cardiac failure. Such studies must wait until compensation has been restored. A concentration test run while a patient is losing edema, for instance, is meaningless.

It is in the edema of heart failure, with normal or relatively normal kidneys, that diuretics are most effective.[6] But all of them are more effective after the patient has been digitalized than before. Digitalis itself,



Digitalis 1.3 Gm.—then 0.1 Gm. daily

Figure 1. The prolonged diuresis produced by digitalis in congestive heart failure

of course, is one of the best diuretics, and is sufficient by itself to get rid of the edema in a large percentage of cases. Moreover, the diuresis from digitalis differs from that of other diuretics in being much more prolonged (Fig. 1). This diuretic action is due entirely to improvement in the circulation, and is not due to any direct action on the kidneys. *The presence of albumin in the urine is not a contraindication to the exhibition of the mercurial diuretics, salyrgan or mercupurin, if these are indicated.* Since their action is due to the inhibition of water reabsorption by the tubule cells, the integrity of these cells as indicated by the excretion of a urine of 1.018 or above is the criteria for their use. If

urine specific gravity is fixed at about 1.010, they will not only be useless, but may do harm.

The use of "acid producing" salts, ammonium chloride, calcium chloride, or ammonium nitrate, with a mercurial diuretic usually increases its effectiveness. They are all irritant to the stomach, and if they produce vomiting not only disturb the patient, but may lead to a relative

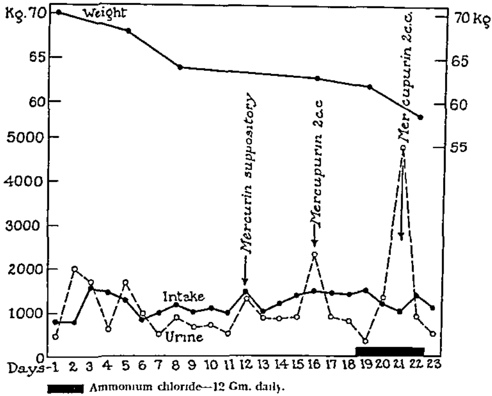


FIGURE 2. The increased diureses usually obtained by giving ammonium chloride with a mercurial diuretic.

alkalosis, which diminishes the mercurial diuresis. If these "acid producing" salts are to be used at all, they must be given in large doses, from 6 to 10 Gm. daily, for if they do not give a fall in plasma carbon dioxide they are of no value. The work of Dennig, Dill and Talbott[7] showed that the degree of acidosis was greater on the second or third day of administration than subsequently, even when the drug was taken continuously. These salts should, therefore, be given intermittently, preferably for two days before and on the day the mercurial is given (Fig. 2).

The presence of any considerable ascites may make sufficient pressure on the renal veins to interfere with the renal circulation and lead to oliguria That this mechanism does occur was demonstrated experimentally by Schmidt and Thorington [8] In such cases digitalis may lead *to other evidences of improvement in the circulation* but little diuresis while a *paracentesis will give a prompt diuresis even without digitalis*

ACUTE NEPHRITIS

Although edema and bloody urine are probably the two symptoms which are most commonly associated with acute diffuse glomerular nephritis changes in the cardiovascular system are just as constant Of these elevation in blood pressure and dilatation of the heart are the most *important While the fact that blood pressure is elevated in acute nephritis is quite commonly recognized the effect of acute glomerulonephritis* on the heart has received but scant attention in this country until recently Yet the occurrence of heart failure in acute nephritis was pointed out by Goodhart in 1879 Volhard[9] has emphasized the frequency of dyspnea orthopnea and pulmonary edema and believing that acute left ventricular failure is the most common cause of death holds that *every acute nephritic should be regarded as an acute cardiac case* Franke [10] Alwens and Moog [11] and others have shown roentgenologically a definite increase in the cardiac area early *in the disease which returns to normal* during convalescence

Levy[12] emphasized the importance of recognizing acute circulatory decompensation in acute glomerulonephritis while Fishberg[13] believed that although evidences of a slight degree of cardiac insufficiency as palpitation and dyspnea are common severe cardiac insufficiency is unusual Usually the apex is displaced down and out and the area of cardiac dullness is increased both to left and right A mitral systolic murmur accentuated aortic second sound and gallop rhythm are not uncommon There are moist rales *in the chest* but *increased venous pressure* and enlargement of the liver are found only in the severer cases Fishberg believed the heart rate is accelerated even in the milder cases while Volhard found a tendency to bradycardia in acute nephritis which he attributed to the acute increase in blood pressure He believed a rate of 50 to 60 per minute is usual in mild cases and a favorable sign while the more

usual pulse rate of about 80 is unusual and a signal to look for signs of cardiac embarrassment Rates over 100 mean danger

Master Jaffe and Dack[14] have reported the electrocardiographic changes in 24 cases of acute glomerulonephritis and reviewed the literature There were significant abnormalities in 19 of the 24 The principal changes involved the T wave the auriculoventricular conduction time (P R interval) and the initial positive deflection in the precordial lead Except for premature beats the only significant arrhythmia was a single instance of auricular flutter Preponderance of the left ventricle was present in nine patients but in only three did it appear or disappear under observation The changes in the T wave were progressive frequently from day to day In some it became large and pointed more commonly low or more often inverted In these a close similarity to the sequence in myocardial infarction was noted although definite R T abnormalities were lacking

It has usually been assumed that the strain placed upon the left ventricle by the sudden rise in blood pressure in acute nephritis was the chief cause of the cardiac insufficiency This explanation does not seem satisfactory For not uncommonly patients with but mild evidence of renal damage as measured by albuminuria or hematuria present the severest degree of cardiac insufficiency Furthermore it is unlikely that a heart of normal structure would fail in the presence of such a transient and moderate increase in work It does not fail for instance in the paroxysmal hypertension due to a tumor of the adrenal medulla or increase in intracranial pressure The changes in the electrocardiogram are those usually considered indicative of diffuse myocardial damage Stone[15] has reported an instance of arteriolitis in the heart in acute nephritis Evidence of all sorts is accumulating which indicates that acute glomerular nephritis is not a disease whose pathological changes are confined to the kidneys but one in which there are widespread vascular changes throughout the body The involvement of the heart is the result of vascular and not of renal damage

In addition to the usual dietetic measures employed in the treatment of acute nephritis special attention must be given to the heart Often rest in bed is all that is required Whenever there is evidence of cardiac insufficiency digitalis should be given Because of the common presence of nausea and vomiting this must frequently be given by rectum or intra

venously Caffeine is occasionally useful but must not be thought of as a diuretic in acute nephritis Here all diuretics are ineffective until the inflammatory process in the kidneys has subsided The most effective measure in acute myocardial failure with pulmonary edema is venesection with the removal of 300 to 500 cc of blood This may be a *lifesaving* procedure

CHRONIC GLOMERULONEPHRITIS

Cardiac symptoms are much less common or prominent in chronic glomerulonephritis than in arteriolar *nephrosclerosis or as it is also called* essential hypertension The cardiac symptoms which do occur in chronic glomerulonephritis are usually proportional to the degree and duration of the hypertension

During the earlier stages of chronic nephritis extremely high blood pressure readings are uncommon Half of Volhard s cases had systolic values between 120 and 180 mm Hg In some patients the diastolic *pressure is elevated out of proportion to the systolic so that readings of* $^{180}/_{130}$ may be obtained This however is not always so There is less tendency for marked fluctuation in blood pressure than there is in early *essential hypertension The hypertension results in hypertrophy of the* left ventricle but this is often relatively slight and the heart may be able to cope with the increased work for years without dilatation

While slight dyspnea on exertion is not unusual severe degrees of cardiac failure are uncommon the chief danger always being the progressive renal insufficiency There are however some long standing slowly progressive cases of chronic glomerulonephritis in which the clinical *picture of cardiac insufficiency develops* With the long-continued hypertension the left ventricle gradually fails Following this a train of symptoms including dyspnea cardiac asthma gallop rhythm and attacks of pulmonary edema *make their appearance Arterial symptoms such as* angina pectoris cerebral angiospasm and spasms of peripheral vessels which are so common in primary hypertension are unusual

Cerebral hemorrhage is also distinctly uncommon in glomerulonephritis But this disease usually occurs in relatively younger individuals whose cerebral arteries are rarely atheromatous When weakness of the right heart also develops engorgement of the liver peripheral edema and all the *other evidences* of congestive heart failure appear It is to be

emphasized that while such a patient has chronic glomerulonephritis, that under these circumstances the edema is cardiac, and not "nephritic," and that the treatment should be that ordinarily employed in congestive failure. Feil and Steuer[16] found that digitalis was just as effective in the presence of nephritis, and that the dosage was the same as in the non-nephritic. It must again be emphasized that marked cardiac insufficiency in the preuremic stages of glomerulonephritis is not common. While dyspnea may be troublesome, both the acidosis resulting from the retention of fixed acids and the anemia contribute to this.

As a rule, with the development of symptoms of true uremia, signs of cardiac insufficiency also make their appearance. It might be thought that the cardiac weakness was primary, the diminished blood flow leading to oliguria, which prevents the maintenance of the compensatory polyuria, and that consequently retention develops and uremia supervenes. This conception, however, is not consonant with the clinical observation that unmistakable signs of fatal uremia, as uncontrollable vomiting, pericarditis, and marked nitrogen retention, may come on without any significant decrease in urine volume There is no doubt, however, that the association of cardiac insufficiency and deepening uremia is not coincidental. For in every case, urine volume, dependent on the renal circulation, *is relatively reduced; that is, it is inadequate for the elimination of* waste at the low concentration which can be attained in the damaged kidney.

On the other hand, in every case the heart may be considered to be inadequate to meet the demand for increased blood flow imposed by the loss of concentrating ability by the kidney. It seems that some retained waste product, or other change in the composition of the blood in uremia exerts a directly deleterious effect on the heart. Thus Wood and White[17] found changes in the electrocardiogram which varied from day to day. Extrasystoles, transient auricular fibrillation, and pulsus alternans are common. The uremic pericarditis was first noticed by Bright. Its etiology has been much discussed, and while some have thought it infectious, the exudate is usually sterile, and it would seem that it is most often, if not always, a sterile inflammation due to some substance retained in the blood as a result of kidney insufficiency.

ESSENTIAL HYPERTENSION

The symptoms, clinical picture and treatment of this condition are discussed elsewhere. In this chapter we are concerned only with the relation of the kidneys to the elevated blood pressure of essential hypertension. As Volhard has remarked, the problem is a beloved but annoying child of internal medicine.

More than 100 years ago, before blood pressure had been determined in man, Bright[18] observed the frequent coexistence of cardiac enlargement, thickening of the arteries and renal disease of various kinds. Finding no obvious cause for the cardiac hypertrophy in the heart or great vessels, he attributed it to an effect produced by an altered state of the blood which he felt convinced was caused by the renal disease. He may thus be regarded as the first to postulate the renal origin of hypertension. Traube[19] was the first to express a definite view of the relation between kidney disease and hypertension, but regarded the latter as the direct result of the increased resistance offered by the narrowed renal vessels. This view has no physiological basis, and has been abandoned by all except those addicted to teleological explanations.

Gull and Sutton[20] confirmed Johnson's[21] demonstration of lesions in the small vessels of other organs than the kidney. Impressed by the widespread nature of the process, which they called "arteriocapillary fibrosis," they concluded that diffuse vascular disease was a pathologic entity and could be responsible for an increase in arterial pressure. Gull and Sutton thus founded a school which stressed the nonrenal origin of hypertension, and has had numerous followers to the present time.

With the introduction of the sphygmomanometer into clinical medicine by von Basch, attempts were naturally made to correlate elevation of blood pressure with changes in the blood vessels. But many cases were found which showed definite elevation in blood pressure, in which arteriosclerotic changes were either absent or minimal. These cases von Basch[22] called "latent arteriosclerosis." Huchard[23] in France, Allbutt[24] in England, and Janeway[25] in this country, believing that the organic disease of the arterioles was not sufficient to produce enough increase in peripheral resistance to account for the observed elevations in blood pressure, suggested that this was due to widespread vasoconstriction. According to this hypothesis, functional vasoconstriction was primary, organic vascular arteriosclerotic changes secondary.

Up to the turn of the century there were three schools of thought concerning the interrelation of hypertension arteriosclerosis and renal disease (1) The followers of Bright who believed that hypertension was due primarily to renal disease (2) the followers of Gull and Sutton who ascribed hypertension to widespread vascular disease and regarded the renal lesions as purely secondary and (3) those who believed with Allbutt that hypertension was due to generalized vasoconstriction unrelated to renal disease [26]

With the separation of contracted kidneys into two groups an inflammatory and an arteriosclerotic by Jores[27] and by Volhard and Fahl [28] a distinct advance was made It was now generally accepted that hypertension was the result of primary renal disease in glomerulonephritis polycystic kidneys obstruction of the urinary passages and renal panarteritis In the other and numerically larger group of patients who *showed hypertension during life and only arteriosclerotic changes in the* kidneys at autopsy the hypertension has usually been regarded as not of renal origin Fishberg for example in the third edition of his book says The concept of essential hypertension includes those cases of chronic hypertension which neither clinically nor anatomically can be demonstrated to have evolved from antecedent inflammatory disease of the kidneys or urinary obstruction While under this definition admittedly unsatisfactory elevation of blood pressure from adrenal or pituitary tumors bulbar poliomyelitis etc would be included he concludes that by far the most common variety of essential hypertension is a constitutional familial and hereditary disease

The usual arguments against the renal origin of essential hypertension have been (*a*) The frequent discovery of elevated blood pressure before there are any recognizable signs of impairment of renal function (*b*) the fact that in a large percentage of these cases renal insufficiency never does become manifest and (*c*) the failure to find any anatomical signs of renal disease in some of these cases The vast majority however do show more or less vascular disease which is frequently more marked in the kidneys than elsewhere For example Bell and Clawson[29] found renal arterial disease in 98 per cent of 420 cases of hypertension and Fishberg found some change in each of 72 cases studied Only Moritz and Oldt [30] among recent workers have attributed particular significance to the renal lesion In a careful objective study of arteriosclerotic changes in the ves

sels of the viscera and muscles from 100 patients with hypertension and 100 with normal blood pressures they found a high degree of correlation between the presence of renal vascular disease and hypertension and no such correlation between arteriosclerosis elsewhere and hypertension

The whole aspect of the problem has been changed and the relation of kidney disease to hypertension greatly clarified by the recent investigation of Goldblatt[31] and his associates The importance of this work can hardly be over emphasized Impressed by the frequent association of renal vascular disease and hypertension Goldblatt argued that *If organic disease of the kidney be the initiating factor in the pathogenesis of benign essential hypertension then this disease is in all probability the arteriolar sclerosis which is so frequently associated with this condition* If arteriolar sclerosis limited to the kidneys can be the primary factor in initiating this type of hypertension then the necessary conditions for the establishment of the renal origin of essential hypertension upon an experimental basis should be the production of hypertension in animals by any method which will produce at least the physiological effects of such renal vascular disease Since there is no known way of producing arteriolar sclerosis localized to the kidney it was thought that the effects of arteriolar disease could probably be produced by constricting the main renal arteries This he did by means of an adjustable silver clamp which could be applied to the main renal arteries and so adjusted as to produce any desired degree of reduction in their lumina Blood pressure was measured either by direct puncture of the femoral artery by a needle connected to a mercury manometer which gives mean pressure or by the van Leersum method In this latter the carotid artery is placed in a tube of skin in the neck so that a suitable small cuff can be placed around it and systolic pressure determined as in *the ordinary Riva Rocci method*

When a clamp was applied to one of the main renal arteries in either dogs or monkeys and moderately tightened there followed in the course of the next couple days a rise in blood pressure of around 50 mm Hg which however usually fell toward or to normal in the course of weeks or months When both renal arteries were constricted the hypertension persisted indefinitely Goldblatt has had such dogs with systolic blood pressures of 200 to 240 under observation for more than five years These animals furthermore in spite of their elevated blood pressure do not show any decrease in kidney function as measured by urea or creatinine

clearance tests or concentrating ability or elevated blood nitrogen If in such an animal, with persistent hypertension, Goldblatt loosened the clamps on the renal arteries, the blood pressure promptly fell to normal. Constriction of other arteries, femorals, splenic, or splanchnic did not produce any elevation in blood pressure. If, however, a clamp was placed

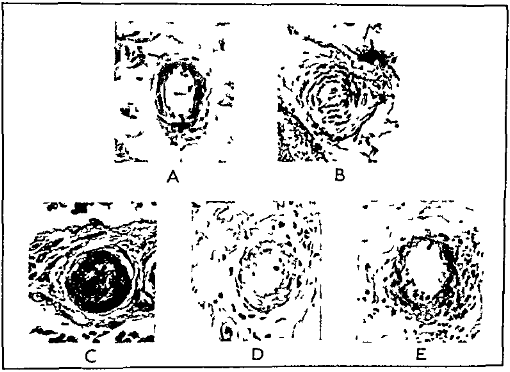


FIGURE 3 Photomicrographs of arterioles from dogs with experimental hypertension due to renal ischemia Kindness of Dr Goldblatt All sections ×232 hematoxylin and eosin stain *A,* Normal arteriole, skeletal muscle *B,* Arteriole of skeletal muscle with hypertrophic media Dog hypertensive four years, no detectable renal excretory insufficiency (benign phase), due to moderate constriction of both main renal arteries *C,* Hyalinized, obliterated arteriole From submucosa of stomach of dog with marked *hypertension and acute renal insufficiency (malignant phase), due to excessive constriction* of both main renal arteries *D,* Necrotic arteriole Submucosa of intestine of hypertensive dog in the acute malignant phase *E,* Necrotizing arteriolitis Submucosa of intestine, hypertensive dog in the acute malignant phase

around the aorta just above the renal arteries, the animal developed hypertension, while if it was placed below the renals no change in blood pressure followed. These results have already been confirmed by several other investigators. In these animals, the only significant abnormalities in the vascular system that Goldblatt has observed have been degenerative changes, mainly intimal, in the arterioles of the retina and the thickening of the media of the arterioles in the other organs, especially skeletal

muscle Other workers have also reported cardiac hypertrophy in such animals

If the degree of constriction of the renal arteries is made extreme Goldblatt finds that the animals not only develop renal insufficiency and die in uremia but that in some there develops widespread fibrinoid and hyaline degeneration with necrosis of arterioles petechiae in intestinal tract serous membranes and many organs but not in the ischemic kid neys These lesions are similar in all respects to those observed in the acute malignant phase of essential hypertension in man (Fig 3)

Pathogenesis The pathogenesis of this experimental hypertension has already been the object of a great amount of study It seems obvious that the increase in blood pressure must be brought about by a general increase in peripheral resistance just as it is assumed in human essential hypertension Since in these animals there can be no initial organic change in the peripheral portion of the whole vascular tree the problem is narrowed to the cause of the functional vasoconstriction which follows narrowing of the renal arteries

Neglecting the teleological explanation of a purposeful elevation in pressure to improve renal blood flow only two mechanisms suggest them selves either a nervous reflex from the ischemic kidneys which affects the general vasomotor apparatus or a humoral mechanism initiated by the ischemic kidneys due to the formation or accumulation in the blood of a substance which directly or indirectly constricts the peripheral vessels The possibility that such a substance might act on capillaries or by neu tralizing a natural depressor substance must also be mentioned [31]

Many experiments from Goldblatt s group and from others have failed to show that a nervous mechanism has anything to do with this type of experimental hypertension Thus denervation of the renal pedicle sec tion of the splanchnic nerves and excision of the lower four thoracic sym pathetic ganglia section of the anterior nerve roots from the sixth dorsal to the second lumbar and even excision of the entire sympathetic nervous system in the thorax and abdomen or pithing have failed to prevent or to cure the hypertension On the other hand if one kidney is removed and the other transplanted to the neck so that there can be no possible direct connection between kidney and nervous system elevated blood pressure

develops when its artery is constricted [32] Thus a humoral mechanism is left as the only probable mechanism

At the end of the last century Tigerstedt and Bergmann[33] obtained a rise in blood pressure in anaesthetized animals by injection of saline extracts of normal kidneys, and actually suggested that there might be an increase in this pressor substance, which they called *rennin* in the kidneys of hypertensives Some investigators confirmed Tigerstedt and Bergmann, others did not, while Collip[34] obtained a nonspecific" pressor principle from a variety of tissues Goldblatt's work has naturally stimulated renewed interest in such experiments

Landis[35] and his collaborators have prepared an extract of normal kidneys which elevates blood pressure without diminishing skin temperature or reducing the amplitude of arterial pulsation Harrison and his coworkers,[36] and Prinzmetal and Friedman [37] have reported a larger amount of pressor substance in extracts of ischemic kidneys of experimental hypertension and arteriosclerotic human kidneys than in similar extracts from normal kidneys Fasciolo, Houssay and Taquini[38] have recently reported that when an ischemic kidney from a dog whose renal arteries had been compressed for from 3 to 10 days is transplanted into the neck of an anaesthetized nephrectomized animal, and the necessary vascular anastomosis completed with carotid artery and jugular vein, the blood pressure of this animal promptly rose 30 to 70 mm Hg, and then remained stable at this figure or slightly lower Moreover, the transplanted kidney could be removed and placed in the neck of still another animal which in turn showed a rise in blood pressure

Attempts to demonstrate a vasopressor substance in the systemic or renal venous blood of hypertensive animals and man have not given uniform results Most observers have failed to demonstrate such a substance in the blood of dogs with experimental hypertension due to constriction of the main renal arteries Houssay and Taquini, however, reported that diluted plasma from such animals exerted an intense vasoconstrictor action on the vascular system of the toad, while similar dilutions of normal plasma had no effect The results of tests made on the blood in human essential hypertension, both benign and malignant, have been contradictory Some obtained pressor effects and others did not The transfusion of large amounts of blood from a patient with hypertension to one with a normal blood pressure was without effect

Goldblatt and his collaborators have thus been the first of a whole army of workers to be able to produce an experimental hypertension in animals which closely resembles essential hypertension in man It can be produced at will persists indefinitely and is not accompanied by any evidence of renal impairment as judged by the usual criteria This experimental hypertension is due to interference with the circulation through the kidneys and is independent of any reflex or influence of the central nervous system The hypertension results from the liberation into the general circulation of some substance acquired by the blood as it passes through the ischemic kidney Whether any of the endocrine glands play an intermediary role in the production of this experimental hypertension is still a little uncertain Of these the adrenal cortex appears the most likely to be of any importance Goldblatt found that bilateral adrenalectomy prevents the development of persistent hypertension while on the other hand in acute experiments Houssay did obtain a rise in blood pressure when an ischemic kidney was transplanted to the neck of a nephrectomized adrenalectomized dog This point will require further study

The failure of any operation on the nervous system to influence experimental hypertension produced by constriction of the main renal arteries does not controvert the results that have been reported following the same surgical procedures in the treatment of hypertension in man If part of the renal ischemia in man were due to spasm of renal arterioles rather than to organic changes improvement of the circulation through the kidneys might result from the various surgical operations on the nervous system as a result of relaxation of these arterioles The fact that lowering of the blood pressure has been reported in about the same proportion of cases following various procedures which directly or indirectly affect the vasomotor nervous mechanism in the abdomen may well be due to improvement of the renal circulation and not as has been suggested directly to the relaxation of the arterioles in a large part of the vascular bed of the abdomen This may also be the mechanism of the fall in blood pressure which is so frequently observed following prolonged vacations or relief from financial or emotional tension for the renal vessels appear to be particularly susceptible to vasomotor impulses

One obvious surgical procedure which suggests itself as a result of Goldblatt s work and to which Goldblatt himself was the first to call atten

tion, is the possible improvement of the blood supply to the kidney by a revival of the old Edebohl's operation of renal decapsulation. In the animals with experimental hypertension the development of an effective accessory circulation by way of the ureteral and capsular vessels at times led to a return of the blood pressure to normal. Since the constriction is only of the main renal artery such accessory circulation can be of functional significance. Unfortunately in human essential hypertension, since the constriction is usually due to disease of the smaller arterioles, collateral communications with the larger vessels would not presumably improve the blood supply to glomeruli and tubules The cases in which the production of accessory circulation would be most effective would be in those rare instances in which the hypertension is due to sclerosis of the main renal arteries or their larger branches The difficulties of such a clinical diagnosis are obvious.

One very interesting practical application of Goldblatt's work has been the discovery in children and adults of hypertension associated with unilateral pyelonephritis and vascular disease and the prompt return of the blood pressure to normal after removal of the diseased kidney. Such cases have been reported by Butler,[39] Barker and Walters,[40] and others.

Patients with essential hypertension constitute by far the largest number of the group that used to be called "chronic interstitial nephritis," although for a number of years before Goldblatt's work, it was thought that the kidney disease had nothing to do with the condition. Fishberg expressed the consensus of opinion "that available evidence demonstrates clearly that renal involvement in essential hypertension is purely secondary, the sequence of events being that hypertension leads to arteriosclerosis and the resultant narrowing of the renal arterioles produces multiple foci of atrophy of the renal parenchyma."

Just as Goldblatt's dogs showed persistent elevation in both systolic and diastolic pressures without detectable evidence of renal impairment, so the great majority of patients with essential hypertension do not show any significant impairment of kidney function. It should be emphasized that less than 10 per cent of these patients die in uremia, or present evidence of renal insufficiency before death. The great majority succumb to cardiac failure, cerebral hemorrhage or intercurrent infection. In most of these patients, tests of kidney function, either the concentration test or urea clearance, are within normal limits. At times there will be a low

excretion of phenolsulfonphthalein with a normal concentrating ability, but this is more properly related to cardiac weakness than to renal impairment. The urine in this group is of normal volume, does not contain an abnormal number of red cells, and frequently no albumin. Other patients may show a slight transitory albuminuria, often related to periods of cardiac weakness, while still others excrete a small amount, less than a gram a day, of protein constantly.

The logical method of treating these patients would be to attempt to improve their renal blood flow. At present direct methods for such an approach have not yet been developed. Quite possibly the benefit that is not infrequently seen to follow periods of rest and relief of nervous and emotional strain in patients with essential hypertension is the result of improvement in the renal circulation, for the kidneys are richly supplied by vasomotor nerves. Certainly nothing except harm is accomplished by restriction of protein or salt or any other particular ingredient in the diet, nor have any drugs been found to be of real value. The general management of essential hypertension is discussed elsewhere in this volume.

A smaller group of patients with essential hypertension do show moderate impairment of kidney function. This is related to the number of glomeruli destroyed by the arteriosclerotic process.[41] Such patients, after several or many years of hypertension, may be unable to concentrate their urine above 1.015 and have urea clearances of 40 to 50 per cent of the normal. They excrete a moderately increased volume of urine, and often have some nocturia. By virtue of this "compensatory" polyuria, they are spared any retention of nitrogen in the blood, nor do they develop any anemia, which is so constantly found in chronic glomerulonephritis. Although the destruction of glomeruli in the kidney by the arteriosclerotic process is progressive, it is usually so slow that the patient dies of cardiac failure or some other cause before the kidney mass has been reduced to a point which precipitates uremia. The number of glomeruli remaining in a kidney does not bear any relation to the reduction in its weight, since the amount of scar tissue, pelvic fat, etc., differs tremendously in different individuals.[42]

Finally, there is a small group of patients, usually in the sixth or seventh decade of life, who have had hypertension for many years, and who, we may suppose, have unusually good hearts, who develop kidney insufficiency and die in uremia. Counts of the number of glomeruli in

such kidneys at autopsy show a marked reduction entirely comparable to that found in patients dying of chronic glomerular nephritis There are normally about one and one quarter million glomeruli per kidney, and this must be reduced to below 500 thousand and usually to below 300 thousand before uremia develops (Fig 4) These individuals are

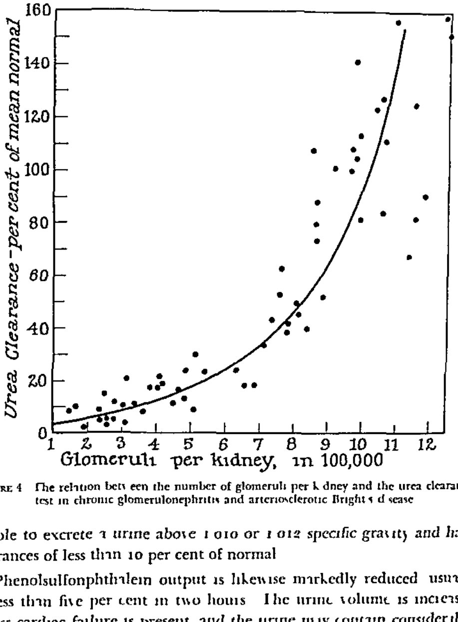


FIGURE 4 The relation between the number of glomeruli per kidney and the urea clearance test in chronic glomerulonephritis and arteriosclerotic Bright's disease

unable to excrete a urine above 1 010 or 1 012 specific gravity and have clearances of less than 10 per cent of normal

Phenolsulfonphthalein output is likewise markedly reduced usually to less than five per cent in two hours The urine volume is increased unless cardiac failure is present and the urine may contain considerable numbers of red cells The hematuria differs from that of chronic

glomerulonephritis however, in this way. While in glomerulonephritis the hematuria is constant, day in and day out, in arteriolar nephrosclerosis it is usually intermittent, the patient showing a number of red cells for a day or so, and then voiding clear urine. This hematuria is much more frequently due to rupture of a small vessel in one of the papillae or in the lower urinary tract than to glomerular damage.

It should also be mentioned that uremia may at times be precipitated in patients with a fair amount of renal reserve by cardiac failure or an intercurrent febrile affection. Either of these may lead to an oliguria which, in the presence of moderate impairment of concentrating power, causes retention in the blood and the consequent train of uremic symptoms.

There is a second group of patients with hypertension who show marked renal impairment usually at the time when they first come under observation. These are often spoken of as "malignant hypertension." They are usually young, at times in the teens, more often in the twenties or thirties. The blood pressure is apt to be very high, cardiac hypertrophy marked, hypertensive neuroretinopathy is present and the development of renal insufficiency rapid. At autopsy, in addition to arteriosclerotic changes there is necrosis in the walls of the smaller arterioles of the kidney and at times in other organs, and reactive changes in the glomeruli. The course is a rapidly progressive one, death in uremia usually taking place within a few months after the patient first comes under observation. Occasionally, patients with benign hypertension and who have shown little or no decrease in kidney function over a period of years undergo a sudden change for the worse manifested by a sharp increase in the degree of hypertension and rapid diminution in kidney function. At post mortem examination these patients also show the arteriolar necrosis characteristic of "malignant" sclerosis.

Etiology. The cause of "malignant" hypertension is entirely unknown. Goldblatt has produced the clinical picture in dogs as well as all the characteristic pathological findings by severe constriction of the renal arteries. It seems not unreasonable to assume that in humans the condition is likewise the result of profound sudden renal ischemia. But we are at present completely ignorant of the factors leading to such a rapidly developing renal ischemia.

Prognosis: The prognosis of essential hypertension, as far as the kidneys are concerned, depends upon the presence and degree of impairment of renal function. When a concentration test shows a maximum specific gravity below 1.015 or clearances below 35 per cent of normal in a young individual with hypertension the outlook is usually very poor. In such patients the renal impairment usually progresses rapidly to nitrogen retention and death in uremia within months or a year or two. In older individuals, past 50, the tempo of the development of the renal lesion is usually much slower, so slow indeed that as has been emphasized above, these patients usually succumb from cardiac failure or cerebral accident before the renal lesion has progressed to the point of kidney insufficiency. An occasional patient develops significant nitrogen retention and tolerates it remarkably well for relatively long periods, even a couple years. But once acute uremic symptoms have developed, particularly if there is accompanying heart failure, the end is not far off.

Treatment: Unfortunately, there is little that can be done for the renal lesion in essential hypertension. In the early stages, the present evidence indicates there is diminished renal blood flow, usually the result of arteriosclerotic narrowing of the smaller renal arterioles, while in the later stages there is a reduction in the number of nephrons. Neither of these are amenable to treatment at the present time. In the absence of nitrogen retention there is no evidence that restriction of meat or other protein in the diet, or of salt, has any effect either on the renal lesion or on the hypertension.

It must not be forgotten that essential hypertension is a chronic disease, and that prolonged protein restriction is apt to result in anemia, lowered plasma proteins, and other symptoms of malnutrition. Diuretics, aside from water, are usually ineffective. With loss of concentrating power, urine volume must be increased to prevent nitrogen accumulation in the blood, but as a rule little is to be gained by a fluid intake in excess of 3000 cc. daily. In cases with a tendency to cardiac edema and impaired concentrating power the dilemma is a real one, the renal condition calling for abundant fluid intake, the cardiac for its restriction. Under these circumstances an unsatisfactory middle ground is the usual compromise. Occasionally in such cases, one of the xanthine diuretics, theobromine sodium salicylate, theophyllin or aminophyllin are helpful. These must

be given intermittently for if administration is continued the diuretic action is lost They are best prescribed in courses of two or three days with an equal time interval between When there is any edema or other evidence of cardiac failure digitalis should be given in the usual manner There is no basis for the fear that it will raise the blood pressure

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CHAPTER XIV

THE HEART IN DISEASES OF THE GLANDS OF INTERNAL SECRETION

By DAVID BARR, M.D

DISEASES OF THE PITUITARY GLAND

PITUITARY INSUFFICIENCY *(Simmonds' Disease, Pituitary Dwarfism)*

Destruction, removal or functional insufficiency of the pituitary gland is followed by a generalized atrophy of all organs and especially of the thyroid, suprarenals and sex glands While the heart participates in this wasting process, clinical evidence of cardiac weakness is not usually apparent. Patients with pituitary insufficiency are, however, subject to attacks of extreme weakness and collapse which resemble those seen in association with Addison's disease. Such crises are accompanied by low blood pressure and are probably attributable to secondary involvement of the suprarenal glands.

ACROMEGALY AND GIGANTISM

Eosinophile tumors of the anterior lobe of the hypophysis are usually if not always responsible for the development of the clinical syndrome of acromegaly and preadolescent pituitary gigantism. They produce somatic changes almost the exact opposite of those found in pituitary insufficiency. There is a general overgrowth of all structures most obvious in the bones, but affecting practically all tissues of the body. The heart may be enormously enlarged. While this is perhaps chiefly attributable to the participation of the heart in a generalized hypertrophy, there are many cases in which the enlargement is out of proportion to that observed in other structures. One contributory factor may be hyperthyroidism, which has been noted in approximately 50 per cent of acromegalics. Diabetes, a frequent concomitant may predispose to coronary disease. Changes in the vascular system may be evident early in the disease. Later a more or less marked arteriosclerosis is an almost constant concomitant.

The blood pressure is variable in some cases being as low as 100 or less while in others it has exceeded 200 mm Hg

The size of some acromegalic hearts is truly surprising Zondek[1] observed radiograms of the heart with transverse diameters from 15 to 17 6 cm In Dean Lewis case- a man six feet two inches in height and weighing 250 pounds displayed a heart at autopsy which weighed 620 Gm Kraus[3] studied a man five feet ten inches in height whose heart weighed 950 Gm Most remarkable of all is the case which was reported by Osborne [4] This man was studied over a period of approximately six years At the time of his death he was 48 years of age His height was five feet nine inches and it was estimated that he weighed approximately 300 pounds He died of syncope and in a manner resembling that described by Marie and typical of death in acromegaly The heart was enormous It weighed 1163 Gm (2 pounds 9 ounces) and measured 15 inches in its greatest circumference The wall of the right ventricle was 3/8 inch in thickness while that of the left ventricle measured 7/8 inch The valves were normal except for some slight thickening at the edges of the aortic cusps The wall of the aorta was not diseased The coronaries were not occluded but were tremendously enlarged so that they admitted an ordinary lead pencil It could not be stated with certainty whether hyperthyroidism had contributed to the enormous cardiac hypertrophy The thyroid gland however was enlarged and there was in the upper mediastinum an extra thyroid which was thought to be hyperplastic That the enlargement of the heart was not due entirely to secondary factors such as hyperthyroidism is indicated by the fact that the weight of the liver and of the kidneys was more than twice the average normal

In the early stages of preadolescent pituitary gigantism there may be extraordinary strength and vigor Later most of the giants have become pitifully weak with edema of the extremities and other evidences of circulatory insufficiency The exact status of these cases has been inadequately analyzed When one considers however, the enormous food requirement of some of the larger giants it seems not unlikely that vitamin B deficiency may at times play a role in the circulatory failure

PITUITARY BASOPHILISM *(Cushing's Syndrome)*

Basophile tumors of the pituitary gland have been not infrequently accompanied by a group of symptoms which include painful obesity of the

face, neck and trunk, with a remarkable absence of fat deposits on the legs and arms; hirsutism with the formation of a mustache or even a beard in women; polycythemia; decalcification of bones tending to affect the spine more than the rest of the skeleton and resulting in a marked upper dorsal kyphosis; impotence in men and amenorrhea in women; and not infrequently a glycosuria or even frank diabetes.[5,6] One of the most striking characteristics of the disease is hypertension. In the series collected by Raab[7] this was seen in 24 out of 26 cases in which the blood pressure was mentioned. The hypertension has varied between $^{175}/_{100}$ and $^{230}/_{100}$. Cases watched over long periods may temporarily display lower systolic pressures, but the diastolic pressure tends to remain constantly elevated. Owing to the dramatic character of other symptoms the heart in Cushing's syndrome has not attracted much specialized study. In autopsied cases in which the heart has been described, however, hypertrophy sometimes quite gross has been a feature. Arteriolarsclerosis may be extreme. In Gouley's[8] case, in which the blood pressure was recorded at $^{220}/_{140}$, death occurred from apoplexy. There was diabetes and a malignant form of hypertension with severe and relatively acute arteriolar disease in the kidneys and to a less extent in the pancreas. The heart was enlarged and weighed over 480 Gm. No specific vascular or valvular lesions of the heart were noted. At present it cannot be stated with certainty whether the enlargement of the heart is entirely a result of the long continued high blood pressure. Although cases have been reported with elevated basal metabolic rates, hyperthyroidism is by no means a constant feature of pituitary basophilism, and the hypertrophy cannot usually be attributed to an associated hyperthyroidism.

DISEASES OF THE PARATHYROID GLANDS

General Considerations. Diseases of the parathyroid glands present problems of great interest because of the accompanying variation in the calcium content of the serum and because of the known physiological effect of calcium concentration upon the contractility of cardiac muscle.

Under normal conditions calcium is maintained in the serum with constancy at a concentration of approximately 10.0 to 11.0 mg. per cent. In hypoparathyroidism following the removal or destruction of the gland the serum calcium may be reduced to a level as low as 4.0 mg. per cent, the reduction being chiefly, if not entirely, in the fraction which may be

considered physiologically active On the other hand in hyperparathyroidism which accompanies hyperplasia or adenomas of the gland the calcium level has been recorded as high as 29 4 mg per cent Again this extraordinary increase cannot be ascribed to a greater concentration of protein or of other factors binding calcium in an inactive form but must be attributed to an increase in the physiologically active fraction

The effect of varying calcium concentrations upon cardiac function has been extensively studied In perfusion experiments it has been found that the presence of calcium in the circulating medium is necessary for the contraction of cardiac muscle A frog s heart perfused with sodium chloride solution soon ceases to beat but can be restored by the addition of calcium and potassium to the perfusion fluid On the other hand calcium salts themselves are toxic when their concentration is unduly increased or when they are not properly counterbalanced by sodium and potassium Within certain ranges the isolated heart of the frog is extremely sensitive to relatively small changes in calcium content of the nutrient fluid Indeed the response is so delicate that the frog heart preparation has been used as a means of estimating physiological variations in the ionized calcium of serum and other body fluids [9] In the perfused rabbit heart it has been shown that slight variations in the calcium concentration of the perfused fluid produce notable changes in the force and duration of systole [10]

HYPOPARATHYROIDISM

From these experimental observations it might be anticipated that the heart would be notably affected by the reduction in serum calcium which accompanies hypoparathyroid tetany Actually the clinical manifestations of functional cardiac changes have not been obtrusive During the frequently long course of the disease the pulse blood pressure and circulation are usually maintained at essentially normal levels The electrocardiogram however has revealed changes which are worthy of note and which are in general similar to those which have been observed in experimental animals Particularly notable has been the prolongation of systole which in some cases may be extreme Skouge s[11] case a patient with thyrotoxicosis had a Q T interval of 0 37 before thyroidectomy Tetany developed immediately after the operation and was persistent There was a progressive prolongation of the Q T interval which three

months after the onset of tetany was 0 62 seconds Marzahn observed a patient with postoperative tetany in whom the systole was prolonged to 0 48 seconds [12] Restoration of normal serum calcium by means of dihydrotachysterol resulted in systoles of normal duration [13]

During the severer attacks of tetany the circulatory changes may be considered a consequence of the muscular exertion and do not differ materially from those observed in other spasmodic or convulsive states In children however sudden death has rarely occurred during sustained paroxysm and has been attributed to spasm of the cardiac muscle [14]

HYPERPARATHYROIDISM

Shortly after the introduction of parahormone its effect on the heart and circulation was thoroughly studied by Edwards and Page [15] To dogs they administered from 20 to 50 Collip units at intervals of two to four hours The total amount injected varied between 13 and 40 units per kg of body weight and resulted in an elevation of serum calcium from normal to values between 15 and 22 mg per cent During the early stages of the experiment the heart rate was increased slightly Later there was slowing and usually a marked arrhythmia with premature beats and shifting of the pacemaker function There were however no constant changes in the electrocardiogram In some records the P waves underwent progressive increase in height during the period of treatment Direct observations on the heart displayed dilatation of the right auricle and it was thought that the change in P waves might have resulted from a greater activity of a slightly stretched auricle There were also changes in the amplitude and direction of the T waves The changes in cardiac function following overdosage with parathyroid extract were compared with those found after injection of large amounts of calcium salts with the conclusion that the effects produced were similar if not identical

No comparable studies have been made in clinical hyperparathyroidism In the uncomplicated cases there are usually no signs or symptoms of heart disease It is possible though not proven by adequate studies that the length of systole is shortened as a result of the hypercalcemia [16] Many cases of hyperparathyroidism are complicated by bilateral nephrolithiasis which may eventually lead to pyelonephritis hypertension and circulatory insufficiency

HYPOTHYROIDISM (MYXEDEMA HEART)

Active interest in the heart in myxedema started with the report of Zondek in 1918.[17] In a study of four advanced cases he demonstrated that both the right and left chambers of the heart might be greatly dilated, that the cardiac action was slow and indolent with normal blood pressure, and that the electrocardiograph revealed characteristic and striking changes. He showed further that these evidences of cardiac involvement could be modified or even reversed by effective treatment with thyroid. To designate this clinical condition he introduced the term "myxedema heart."

Zondek's observations were repeatedly confirmed[18,19,20] and led to clinical and experimental studies which clearly established the fact that prolonged hypothyroidism may have a profound influence upon the heart and circulation.

Pathology: At autopsy some degree of dilatation or hypertrophy of the heart has usually been demonstrable. Of the 20 autopsied cases collected by the Clinical Society of London,[21] one third revealed hypertrophy of the left side of the heart. In nine autopsies studied by Means[22] a pseudohypertrophy possibly due to swelling of muscle fibers was grossly evident in several. It has been suggested by many observers that the changes in the heart may be attributed to an edematous condition of the cardiac muscle similar to that seen in other tissues of myxedematous patients. Microscopically, however, a variety of pathological changes has been described.[23] Among these are destruction of muscle fibers, thickening of the leaflets of the aortic valve and accumulations of a homogeneous material which has an affinity for hematoxylin but which does not display the staining characteristics of the myxedematous infiltration found *in the skin*.[24]

In thyroidectomized animals, hearts have been shown to be dilated, pale and flabby. Microscopically there has been a decrease in the number of muscle fibers with degeneration and disappearance of perinuclear sarcoplasm in some of those which remain.[25] Simpson[26] found that early thyroidectomy in sheep presented abnormal development of the sarcoplasm. Edema has been shown not only by the gross appearance of the muscle itself but also by measurements of actual water content.[27]

Effusion into the pericardium has been found both in autopsied cases of myxedema and in experimental hypothyroidism.[25,27,28] This may

be accompanied by ascites and by pleural effusion Means[22] states that in his experience the serous cavities of untreated cases invariably contained fluid In one of the autopsied cases of the Massachusetts General Hospital there were 3000 cc of serous fluid in the peritoneal cavity 1500 cc in the two pleural spaces and 1000 cc in the pericardial sac

Lesions of the blood vessels have been frequently demonstrated Atheroma of the arteries was apparent in more than half of the 20 autopsied cases of the Clinical Society of London [21] Sclerosis of the aorta the coronaries and other arteries was shown in the early studies of von Eiselberg [29] Pick and Pineles[30] found similar changes following thyroidectomy in young goats Subsequent studies have tended to confirm the impression that a prolonged state of hypothyroidism accelerates the development of atheroma which however is not a constant or inevitable accompaniment [31]

As early as 1908 Saltykow[32] *suggested that the arterial lesion of myxedema resembled medial necrosis This idea has recently received support from the demonstrations of Kountz and Hempelmann* [33] *who reported spontaneous rupture of the aorta in three cases in which complete thyroidectomy had been performed during the course of malignant hypertension Examination of the aorta revealed in all of them lesions apparently identical to the cystic medial necrosis of Erdheim* [34] *Recently we have been able to show exactly similar lesions in a severely myxedematous patient who had during life no evidence of hypertension* [35]

Clinical Manifestations *Functional Disturbances* In the myxedematous state it has been shown that the velocity of blood flow is diminished and that the cardiac output per minute and per beat is decreased Studies of arterio venous oxygen differences have revealed that the circulation rate is less than could be accounted for by the lower oxygen requirements of the tissues [36]

Enlargement of the Heart The size of the heart shadow in the teleoroentgenogram is increased in most myxedematous patients Of 48 cases studied by Lerman Clark and Means [37,38] 34 showed a transverse diameter of the heart which exceeded by 1 cm or more one half the diameter of the chest in 22 the transverse measurement was 5 cm or more in excess of half the chest diameter

The cause of the enlargement is still a subject of dispute That it is not due to hypertrophy of the cardiac musculature is clearly indicated by

the rapidity with which the size of the heart decreases during treatment The most obvious explanation would be that the heart, like other tissues, contains an increased amount of interstitial fluid Pathologically, however the extent of demonstrable edema of cardiac muscle does not readily account for the clinical observations Dilatation of some degree has usually been assumed and has been demonstrated in many autopsied cases and in the hearts of thyroidectomized animals [25] Gordon[39] has suggested that the supposed enlargement of the heart is attributable to accumulation of fluid in the pericardium He emphasized that the appearance of the roentgenographic shadow of the myxedema heart of Zondek closely resembles that of pericardial effusion, also, that fluoroscopically the heart borders move sluggishly in both conditions Fahr has stressed as possibly the only point in differential diagnosis that the diameter at the base of the heart is much narrower in myxedema than it is in the presence of massive pericardial effusion Unfortunately, in some cases[40] of myxedema with excessive accumulation of fluid in the pericardium this differentiating sign has been absent In considering the available evidence certain facts must be emphasized (1) That pericardial fluid has been demonstrated clinically in a number of cases of advanced hypothyroidism [39 40 41 42] (2) that some degree of accumulation of fluid in the pericardium of autopsied cases has been an extremely common finding and (3) that in most of the clinical cases of gross enlargement of the heart in myxedema the possibility of pericardial fluid has not been entirely excluded

Clinical evidence indicates that great enlargements of the cardiac shadow are encountered only after a patient has been in a hypothyroid state for several years The degree of physical activity and of other factors of strain such as hypertension are no doubt contributory Zondek s[43] German officer was shot through the thyroid gland in 1914 Three years elapsed after the destruction of the gland before severe signs of cardiac involvement developed Fahr[44] observed a patient who had been successfully treated for myxedema but who had discontinued therapy Eight months were required before an enlargement of 3 cm in the transverse diameter of the heart could be demonstrated

Cardiac Decompensation In the literature there is no agreement as to the incidence of congestive heart failure Of 162 cases of myxedema studied by Willius and Haines [45] 91 per cent were said to be free of subjective or objective signs of organic cardiovascular disease In the remain

ing nine per cent the lesions were accounted for by etiological factors other than myxedema. On the other hand, Fahr,[14] in a study of 17 cases, found five with evidence of serious heart failure, while eight others showed dyspnea, pitting edema, reduction in vital capacity, râles at the pulmonary bases and some degree of dilatation of the heart. It is difficult indeed to explain such varied experience. Most observers agree that extreme degrees of decompensation are uncommon, except when other organic heart disease is present as a complication.

Angina Pectoris: The association of precordial pain with myxedema was noted as early as 1914 by Hertoghe[46] and was mentioned by Zondek[17] in his original account of the myxedema heart in 1918. Characteristic angina pectoris was reported by Laubry[47] in 1924. Although complaint of precordial aching is not uncommon the incidence of severe pain appears to be quite uncommon. Willius and Haines[15] in their 162 cases of high grade myxedema mention only one in whom twinges of pain followed the full use of thyroid. Lerman, Means and Clark[37] saw one case of angina in 18 patients, while others[45, 49, 50] make no mention of the symptom. When one considers the incidence of atheroma of the coronary arteries it is perhaps surprising that angina has not been found more frequently as a spontaneous symptom.

Hypertension: Zondek in his original description of the myxedema heart specifically mentions the normal blood pressure accompanying the cardiac enlargement. Actually hypertension is by no means rare. Among 90 cases studied by Froment and Jeune,[51] 22 showed pressures above normal, 59 were within normal limits and only nine revealed hypotension. In Means'[22] 48 patients the blood pressure before treatment varied from 88/64 to 190/130. In the fatal case of Lenegre and Fleurot[52] the blood pressure was 220/110. Thompson and his coworkers[53] have presented evidence that the incidence of hypertension is greater in successfully treated myxedematous patients than it is in the general population.

Cardiac Irregularities: Sluggish heart action with slow pulse is apparent in most well advanced cases of hypothyroidism. In some patients with low metabolism, however, the heart rate may be accelerated. Auricular fibrillation is rare.[54, 55, 56] Gardner[57] in a single case noted periods of auricular flutter with arborization block. Nodal paroxysmal tachycardia alternating with sinus bradycardia was reported by Lisser and Anderson.[58] Paroxysmal auricular tachycardia has also been noted.[54] Increased

auricular ventricular conduction time is not very uncommon[54, 59] A high degree of partial heart block was reported by Luten[60]

Electrocardiographic Changes Some degree of abnormality in the electrocardiogram is extremely common in myxedema and in cretinism Froment and Jeune[51] found pathological changes in 106 of 163 cases Ohler and Abrahamson[54] in 13 of 21 cases while Lerman Clark and Means[37] found abnormalities in all of their patients with well developed myxedema The most constant feature is a flattening or inversion of the T waves particularly in Lead II This may be accompanied by abnormal axis deviation by a diminution in the amplitude of the QRS complexes and by small P waves Such changes are observed in many cases of hypothyroidism in which thorough clinical and radiographic examination reveals no cardiac abnormality The exact cause of the electrocardio graphic changes is not clear The suggestion that they might be due to the altered resistance of myxedematous skin has not been substantiated That they are not attributable directly to the decreased rate of oxidation is shown by the work of Reid and Kenway[61] who found no abnormalities in the electrocardiograms of persons having low metabolism without myxedema

Treatment If a patient has not been too long neglected and if there are no serious complicating arterial lesions treatment may be extremely satisfactory Digitalis has been notably unsuccessful in relieving failure of myxedematous hearts Thyroid on the other hand accomplishes in most cases prompt and often dramatic improvement

Following thyroid medication the sounds of the heart gradually become more audible and the pulse rate increases As the basal metabo lism returns to normal the output of the heart per beat and per minute *is increased and the velocity of blood flow is augmented*[36]

The size of the heart shadow diminishes The degree of change varies but may be very great In one of Fahr s cases there was a shrinkage of 6 3 cm in the transverse diameter over a period of seven weeks Ten of Lerman s[37] 12 patients exhibited progressive decrease in cardiac measure ments reaching a maximum in periods varying from three weeks to six months

Diminution in the abnormalities of the electrocardiogram is apparent in almost all treated cases and may develop rapidly Flat or inverted T waves become normal in appearance the amplitude of the QRS com

plex is increased and the P waves become normal or in some cases unusually prominent

The effect of thyroid medication on the level of blood pressure cannot be predicted Changes were noted in 37 of Means[9] 48 cases In 20 of them the systolic pressure dropped 10 mm or more while in 11 cases it rose 10 mm or more *Variable changes were also noted in the level of* diastolic pressure In most of the patients there was slight increase in pulse pressure A gratifying result of treatment has been noted in some of the cases in which hypertension has been a feature[illegible] In Means series 11 cases had high blood pressure before the institution of therapy In five of these the blood pressure returned to normal while in six others the level of blood pressure was lowered

Thyroid therapy has at times affected the rare cardiac irregularities of myxedema In two[illegible] of three cases of auricular fibrillation the use of thyroid without other drugs was followed by a return to normal sinus rhythm Gardner s[7] auricular flutter with arborization block the nodal tachycardia of Lisser and Anderson[illegible] and the paroxysmal auricular tachycardia of Ohler and Abrahamson[illegible] disappeared following thyroid medication

It should be emphasized *that there is no reason for rapid administration of thyroid in cases of myxedema* Usually the changes consequent to the hypothyroidism have progressed over a period of months or years Rapid return to a normal state may be accompanied by discomfort and in patients who present evidences of cardiac decompensation or signs of arteriosclerosis of the coronaries or other vessels may be extremely hazardous

In the rare case of *cardiac failure thyroid medication by increasing the metabolism and thereby increasing the work of the heart may pre*cipitate an acute decompensation A more imminent danger presents itself in patients whose coronary vessels are extensively diseased In 19[illegible]5 Christian[illegible] reported a case of a woman of 50 who died of coronary infarction 16 days after thyroid medication was begun Since that time a number of accidents have been reported[illegible] *These have been recently collected by Smyth*[illegible] *It is no*table that the accidents have occurred in patients past middle life with ages running from 49 to 63 In these cases the coronary attacks have occurred under circumstances which suggest a causal relationship rather than mere coincidence

In the treatment of most cases of myxedema and especially of those discovered in later life or exhibiting signs of cardiac involvement or arteriosclerosis, the initial dose of thyroid should not be greater than 0.06 Gm. (1 grain) per day. This may be cautiously increasely as the tolerance and requirements of the patient become apparent. When myxedema is accompanied by cardiac disease, the patient should be under constant and detailed observation during the period of readjustment

DISEASES OF THE SUPRARENAL GLANDS

ADDISON'S DISEASE

A small heart and a small aorta have frequently been described in Addison's disease and have been regarded as due to an atrophy secondary to the disease itself and particularly to the hypotension and circulatory weakness The condition of the heart was carefully studied by Barker,[67] who was able to assemble 21 cases in which the heart had been weighed. Using the table of average normal weight with upper and lower limits, as devised by Smith from total body weights, he found that the weight of the heart was less than the average normal in 15 cases, and greater than the average in six. This would seem to indicate that there is actually a specific diminution in the size of the heart as an accompaniment of Addison's disease. The deduction, however, is rendered somewhat invalid by the fact that most patients with Addison's disease, particularly those in whom there is an accompanying tuberculosis, tend to lose large amounts of weight. It is well known that a certain amount of atrophy of the heart may be expected from loss of weight due to any cause. The Addisonian crises, so frequent and so justly feared in adrenal insufficiency, are usually accompanied by vomiting, weakness and extremely low blood pressures These are probably associated with peripheral vascular functional changes and cannot be attributed to any specific cardiac weakness or pathology.

CORTICAL TUMORS AND HYPERPLASIA OF THE SUPRARENALS

The clinical syndrome associated with adrenal adenomata, carcinomata and even with hyperplasia of the gland cannot be differentiated from that of pituitary basophile tumors or Cushing's syndrome. The same bodily changes may be present. There is the same tendency to diabetes, polycythemia, sexual atrophy and also to hypertension. In these conditions also there may be hypertrophy of the heart. That this is secondary

to the high blood pressure is generally assumed, but studies have not been sufficiently detailed or careful to justify any final conclusion.

BENIGN CHROMAFFIN CELL TUMORS

In 1922 Labbe, Tinel and Doumer[68] reported a case of a married woman of 28 who suffered from frequent paroxysmal attacks of high blood pressure, during one of which she developed a fatal pulmonary edema Autopsy revealed a tumor of the left adrenal gland Five years later C. H. Mayo[69] successfully removed an adrenal tumor from a young woman with similar symptoms, which were completely and permanently relieved by the operation

Sudden and wide fluctuations in arterial pressure are not unusual in essential hypertension and have been noted in association with a number of pathological conditions When, however, the fluctuations are marked and particularly when they are paroxysmal in character, the presence of a phaeochromocytoma or tumor of adult chromaffin cells of the adrenal medulla must be suspected Although rare, a phaeochromocytoma is clinically important because of its benign character and because its surgical removal may result in complete clinical cure of a distressing and eventually fatal disease

The attacks of high blood pressure that accompany these growths have generally been attributed to sudden massive discharge of epinephrin, a supposition which is supported by analyses of the tumors themselves Ordinarily both human adrenals contain only about 8 mg of epinephrin In a single phaeochromocytoma, however, as much as 375 mg of epinephrin have been recovered [70]

The paroxysms are characterized by abrupt elevation of systolic blood pressure, which in one case was recorded at 310 mm Hg [71] In many instances it has exceeded 300 The diastolic pressure is more variable Even with excessive systolic pressure it may be only moderately elevated On the other hand it has been recorded as high as 240

In the same patient paroxysms may display great variability both in duration and severity They may last for minutes or hours. Some of the milder attacks may pass almost unnoticed, while others are accompanied by most alarming symptoms Palpitation due to a rapid and vigorous action of the heart is an almost constant accompaniment. The extremities usually become blanched, cold, mottled and sometimes painful. There

may be nausea and vomiting, violent headache and drenching sweats. Pains in the lumbar and other muscles may be distressing.

Precordial pain with radiation to the neck and down the arm has been frequently noticed. If the attacks are severe or prolonged there may be signs of cardiac incompetence with sudden engorgement of the veins of the neck, enlargement of the liver, and pulmonary edema.

The electrocardiographic changes during paroxysms have been variable and are not sufficiently characteristic to aid in diagnosis. Very high T waves have been reported In one case there were cardiac irregularities at the end of attacks with short runs of auricular tachycardia, ventricular extrasystoles and ventricular tachycardia. Diphasic T waves have been observed in the first lead In another case a shift of the pacemaker from the sinoauricular to the auriculoventricular nodes was noted.

Between attacks there may be no symptoms. In the early stages of the disease the blood pressure is usually if not always normal. When the condition lasts long enough, however, the pressure tends to become permanently elevated. At times the permanent changes have been seen to develop rather rapidly, as in the case of Rabin,[72] in which in six months the blood pressure between attacks had risen from $^{140}/_{90}$ to $^{210}/_{130}$. Electrocardiograms which have been studied between attacks in about one-half of the cases were usually normal. Evidence of left preponderance, notching of the T waves and large T waves have been reported.

In 11 of the 18 proven cases which were studied by Howard and Barker,[73] nine survived the surgical removal of the causative phaeochromacytoma and were completely relieved of their symptoms.

DISEASES OF THE PANCREAS

DIABETES MELLITUS

While diabetes is not known to affect the heart directly, there can be no doubt that it predisposes to early arteriosclerosis, arteriolar sclerosis and coronary heart disease [74] In many cases hypertension may precede by several years the onset of diabetes In others it tends to develop during the course of the disease The symptom of angina pectoris is frequent. Root and Graybiel were able to collect 210 cases of angina among 7000 diabetics[75] and a further analysis revealed 410 among 10,000 [74] Coronary thrombosis is a common complication and may occur at an early age.[76] Clinically the character of arteriosclerotic heart disease arising in the

course of diabetes does not differ significantly from that ascribable to other etiological factors

HYPERINSULINISM

Tumors and hyperplasia of the islands of Langerhans may give rise to hypoglycemia which may be accompanied by symptoms of weakness profuse sweating anxiety faintness syncope or convulsions In this syndrome the heart does not appear to be primarily or obviously involved Theoretically however a continued hypoglycemia might tend to deplete the glycogen content of the heart muscle and thus lead to cardiac weakness and circulatory collapse *In electrocardiograms Middleton and Oatway[77] found a depression of the T wave in all of the cases of insulin shock which they studied In animals with insulin hypoglycemia Soskin Katz and Frisch[78] demonstrated inversion of T waves which did not* always return to normal after the injection of glucose solutions Experimentally it has been shown that while the isolated normal heart is capable of storing glycogen during insulin administration the diabetic heart does not store it unless the blood sugar is maintained well above the normal level[79] Death from cardiac infarction has been reported after a rapid fall in blood sugar from the administration of insulin[80] Because of this evidence there has been some apprehension concerning the use of insulin in patients whose hearts are decompensated and particularly in those who suffer from angina pectoris or present symptoms of coronary sclerosis Strouse and his associates[81] found that some of their patients with coronary disease experienced increasing precordial distress as the diabetic state was corrected by insulin Joslin[64] has emphasized however that many diabetic patients with incompetent hearts have been benefited with the cautious use of insulin All observers agree that *in cardiacs, great care must be exercised to avoid hypoglycemia The diet should be regulated gradually and insulin should be given at first in very small doses*

DISEASES OF THE THYMUS

STATUS THYMICOLYMPHATICUS (*Lymphatism*)

In 1889 Paltauf[5] introduced the concept of a lymphatic constitution characterized anatomically by prominence of the thymus gland and of the lymphoid tissue and at times by hypoplasia of the aorta clinically by sudden death either spontaneously or from trivial causes Since that time there has been much discussion concerning the nature of the condition

and more recently concerning its existence. The undoubtedly important medicolegal aspects of the concept finally led the Medical Research Council in conjunction with the Pathological Society of Great Britain and Ireland to appoint a committee for its thorough investigation. Their studies were published in 1931 by Young and Turnbull.[83] The commission found little if any association between the weight of the thymus and the amount of lymphoid tissue in various parts of the body. They could discover no evidence of an association between arterial hypoplasia and an abnormally large thymus nor could they establish any valid relation of sudden death to the size of the thymus They concluded that the so-called status thymicolymphaticus has no existence as a pathological entity. An interesting sidelight upon the original contention of Paltauf comes from studies of Hammar,[84] Boyd[85] and others who have shown that the thymus with malnutrition or disease tends to undergo rapid diminution in weight and that its normal size can only be ascertained in persons who die suddenly or after a short illness

DISEASES OF THE SEX GLANDS

Atrophy, destruction or removal of the sex glands either in men or women may be followed by neurocirculatory symptoms. In female castrates and in women at the time of the menopause recurrent sensations of flushing or of suffocation, palpitation and tachycardia may result in serious incapacity.[86] There is no evidence that the heart itself is affected Instability is typical of the menopausal syndrome and is reflected in fluctuations of blood pressure which may vary greatly from hour to hour. There has been much dispute concerning a possible etiological relation between the menopause and hypertension.[87] Maranon[88] believes that more than 50 per cent of women at the climacteric exhibit some elevation of blood pressure. Many others have noticed a high incidence of hypertension It must be remembered, however, that the age of the normal menopause is also the age when arteriolar changes tend to become evident and that moderate or advanced hypertension is relatively frequent both in men and women during the fifth decade.

Observations of the possible effect of ovarian hormone on the level of pressure during the climacteric have been too fragmentary to permit conclusions.

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CHAPTER XV

TRAUMA OF THE HEART

By Hugh Barber M D

Introduction Trauma of the heart may arise as the result of wounds and direct violence and also from strain of effort From one or other of these causes varied lesions may develop but the cases are exceptional it is difficult both to collect the evidence and to assess it judiciously There are two chief problems On the one hand when a definite heart lesion is manifest after violence or strain we must rely chiefly on the medical history in making a decision as to whether the condition is the result of trauma or is due to natural causes and if due to trauma as to whether the heart was already diseased before the event in question On the other hand following injury or alleged strain we meet with apparent disease of the heart as for example a possible contusion of the myocardium or a case suggesting cardiac overstrain when it may be difficult to decide as to whether the heart itself has been injured at all

Experimental work with regard to direct violence has indicated the possibility of numerous lesions occurring as the result of this form of trauma but most experiments relating to strain or overstress of the heart have proved that all parts of the healthy heart are capable of withstanding considerable strains

The function of the heart as judged by exercise tolerance tests is hard to assess White in 1937 drew attention to the fact that neurocirculatory asthenia and muscular flabbiness are more easily exposed by exercise tolerance tests than is true heart disease We are compelled to place considerable reliance on the patient s own statements when they are consistent Modern methods of investigation have helped sometimes with regard to the condition of the heart muscle in cases of trauma but only if the opportunity for examination is taken early and probably in the majority of cases of myocardial injury the findings would be negative

Perhaps the extended use of instruments of precision has tended to lessen our interest in case histories. All forms of trauma are becoming increasingly bound up with litigation, which militates against an open mind. Trauma of the heart is essentially a study of case histories, using the word history in the widest sense of that term.

The subject may be divided under the following headings: (1) Disorders of rhythm; (2) valvular disease, (3) contusion of the heart, (4) wounds of the heart, and (5) primary cardiac overstrain. In some cases of contusion of the heart, a disordered rhythm or a valvular lesion may be coexistent. It is easy usually, but not possible always, to distinguish between direct violence and internal stress

Spontaneous rupture of the heart muscle is, of course, the result of coronary disease. Goodall and Weir in 1927 recorded 18 cases, but in only four was there evidence of emotion or strain Such an event can hardly be included in trauma of the heart.

DISORDERS OF RHYTHM

1. AURICULAR FIBRILLATION

When this condition develops in the course of the natural history of a diseased heart, it is possibly the result of the many small strains which daily life entails. It may arrive, however, as a suddent event, as the result of overstrain or direct violence to the chest wall. In some cases mental excitement may be an added factor. The recorded examples usually have been middle aged or elderly men, but some of them would appear to have had a heart perfectly normal before the trauma. Hay and Jones in 1927 recorded five cases of auricular fibrillation, of which four were due to sudden physical exertion, and one to electric shock. They state that four of the patients were apparently well before the exciting cause or accident. Two of them were under 40 years of age.

Two cases, the result of overstrain, have come under my own observation. One was a man known to have mitral stenosis, but leading an active life until a sudden unexpected lifting effort caused distress with fibrillation supervening. The other example is as follows:

A workman in good health, aged 55 years, undertook some heavy lifting work to which he was not accustomed Sudden pain developed across the chest and he felt weak and dizzy. He was short of breath going home and this symptom increased. He rested at home for a fort-

> night and his doctor noted an irregular heart This was confirmed as auricular fibrillation by electrocardiogram There were no other abnormalities Five weeks after the strain normal rhythm was restored by quinidine

Kahn and Kahn in 1928 recorded cases of auricular fibrillation following direct trauma of the chest wall It is the predominant feature in two cases recorded by Kissane in 1927 as contusion of the heart I have met with it on two occasions after a man has been knocked down by a motor car There was no evident bruise on the chest wall or actual history of blow over the heart so that direct trauma sudden strain and excitement may have acted together Both were elderly and possibly liable to the disability but in good health for their years To take one example already recorded (Barber 1938)

> A man aged 61 years acting as a night watchman was knocked down by a motor car on January 21 1932 He was taken to the casualty department at the Derbyshire Royal Infirmary about this he remembers little After being detained for a few hours he was sent home by car to rest in bed He noticed that he was short of breath and his doctor recognized an irregular pulse The shortness of breath persisted and although his external injuries were trivial it was obvious that his capacity for exertion was entirely changed Seen by myself in December 1932 auricular fibrillation was recognized by electrocardiogram There were no other abnormalities There was no congestive failure Five years later his condition was unchanged

My other patient had a scalp wound which is of interest because Bramwell in 1934 has recorded the case of a coal miner aged 35 years in whom auricular fibrillation was present after a blow on the head

We may conclude that auricular fibrillation is a definite disability which may result from trauma either in the form of direct violence or more commonly from overexertion When the disability is the result of overstrain there is distress at the time with dyspnea on slight exertion In those cases due to direct violence the cardiac symptoms may be masked by the shock of the trauma and there may be delay before the fibrillation is recognized In hearts already diseased the life history is changed The event may take place when the heart previously was efficient and apparently normal In a number of cases quinidine has restored normal rhythm but relapse may occur

2. AURICULAR FLUTTER

The disposing causes of this condition are similar to those which produce fibrillation, but I have seen no case records in which trauma was the exciting cause. Walker in 1933 admitted this event and White in 1937 stated that flutter is commonly precipitated by sudden effort, excitement, trauma or surgical operation.

One case of auricular flutter came under my own observation in 1935 after a fracture-dislocation of the cervical vertebrae. From the hospital records it would appear that flutter developed several days after the accident whilst in bed. It is difficult to find a reasonable explanation, but the fact remains that when the man recovered from his surgical injuries he was incapacitated by reason of the heart condition. There was evidence of a hypertensive heart, but one cannot entirely ignore the injury as a possible exciting cause of the flutter.

3. EXTRASYSTOLIC ARRHYTHMIA

This irregularity is not a definite entity and is no disability in itself. We may only conclude that there is an irritable focus in the heart muscle. It is present sometimes after overstrain, real or alleged, and is perhaps due to a neurosis in some of these cases. It has been met with after a blow over the precordium, in which case there may have been some injury to the pericardium or heart muscle. Judicious treatment should minimize the significance of any symptoms which may result from this arrhythmia. Tobacco or other disposing causes must be considered. But although extrasystoles in themselves have little influence on the heart capacity, they are rarely met with in hearts that are perfectly normal, and they have some significance after trauma. Kissane in 1937 produced ventricular extrasystoles experimentally in dogs after a blow over the chest.

4. HEART BLOCK

This form of arrhythmia indicates a lesion deep-seated in the myocardium. It may arise from direct violence; that it could result from effort is improbable. Walker in 1933 and also White in 1937 stated that it may result from direct trauma. Kissane in 1937 produced this condition experimentally in dogs and has found it in contusion of the human heart. Experimentally it was transient and soon passed off. A serious injury to the auriculoventricular bundle with survival of the patient must be an exceptional event; but Coffen in 1930 described complete heart block,

persisting seven years after a child of three years of age had fallen four or five feet on to his chest There was no external bruising (Just before the accident he scored 98 per cent in a baby clinic examination) The slow pulse which persisted was recognized within a few hours of the accident

VALVULAR DISEASE

1 From Strain Rupture of a valve from strain or overexertion is a lesion well known which has been recognized for more than 100 years Peacock in 1865 discussed the problem in his Croonian Lectures There is immediate and urgent distress with precordial pain There will follow varying degrees of heart failure The physical signs of a traumatic valvular lesion are similar to those of valvular disease due to natural causes The diagnosis of trauma is based on an accurate history and if possible evidence with regard to the heart condition previously Sometimes there is a bruit of unusual type or intensity and in one of my own records the patient himself could hear the unusual noise which developed after a lifting effort

The aortic valves are those most liable to this form of injury There is evidence that the valves were already diseased before the accident in the majority of cases but there are some records (Howard 19°8) in which it would appear that the valves were not affected with rheumatic syphilitic or other chronic disease although of course there may have been some slight defect of structure There is no doubt that many of the patients have had no consciousness of disease before the event

Rupture of a mitral valve from strain is rare although it has been recorded by Allbutt in 1870 and 1873 and by several other observers A more probable accident in this region is rupture of one of the chordae tendinae which gives rise to similar signs and symptoms Peacock in 186, recorded the event after severe vomiting in a child with well compensated mitral stenosis and Horton Smith in 190? described rupture of chordae tendinae in a workman aged 33 years due to strain There was immediate pain with dyspnea followed by passive congestion He died in three months At autopsy the valves showed no evidence of previous disease

Allbutt in 1870 in mentioning certain cases in which a sudden strain appears to have caused structural damage suggests these may be extreme instances of an agency always at work in some degree in those who do

heavy manual work This is an interesting speculation particularly in relation to sclerosis of the aortic valves but it takes us beyond the scope of this article, and of course the traumatic lesions under consideration here are met with in all walks of life

Defects of other valves from strain are improbable although possible A medical colleague has described to me the development of a bruit during effort with comparatively little distress subsequently which is suggestive that the foramen ovale had become patent

2 From Direct Violence It has been proved experimentally in the post mortem room by a number of observers that heart valves can be ruptured by a blow over the chest wall which does not produce external injury In some accidents external violence and internal stress may act together

In the type of case to be considered here the presumption is that the valves were healthy and there is less need to discuss the possibility of *antecedent chronic valvular disease We must realize however that in* those exceptional patients who survive the event of rupture of a valve from direct violence some healing will take place and eventually the physical signs will be indistinguishable from those met with in valvular disease due to natural causes At such a stage the history and past medical evidence is the only guide on which to base the etiology of the valve lesion This point is illustrated by two examples of my own already published (Barber and Osborn in 1937)

> A man of 32 years of age joined up at the beginning of the war in 1914 with a previous history of good health and athletic activity He served a year in the front line In 1915 he was blown up and buried in the debris A day or two later he recovered consciousness to find his heart very distressed There was no external injury He was five years in one hospital and another From 1919 until his death in 1937 from pneumonia he was under my own observation many times It was obvious in 1919 that the mitral valve was diseased there being a systolic bruit and a *localized mid-diastolic sound* Five years after the injury he could sit out of bed and he improved gradually By 1930 (15 years after the injury) the physical signs were indistinguishable from those of mitral stenosis of rheumatic origin There was a presystolic thrill and bruit localized to the mitral area His condition remained stationary When he died from pneumonia 22 years after the injury the stenosis was obvious and there were features which confirmed *beyond doubt the diagnosis of trauma*

> The evidence is conclusive that the mitral valve was normal before the trauma At a stage when the clinical features were typical of mitral stenosis the trauma could only be recognized through the detailed history

By way of contrast I have the following record (Barber 1938)

> At a coroner s post mortem in 1937 at the Derby City Hospital I was present when Dr Osborn demonstrated disease of the aortic valves very suggestive of being the result of trauma There was an old fracture of the sternum over the base of the heart The man was wounded in the leg during the war in 1916 when a front line soldier so that presumably his heart was normal Whilst he was in a casualty clearing station the sternum was fractured by a fall of roof in an air raid after which he was invalided out of the service The history is so fragmentary that it is not possible to make a definite diagnosis of traumatic disease of the aortic valves but it is the most probable explanation The aorta itself was particularly healthy as also was the mitral valve
>
> The case was accepted as death resulting from war service but scientifically it is not proved in the absence of any records which help to assess the heart condition soon after the fracture of the sternum

Kissane Koons and Fidler in 1936 reported a case of rupture of the aortic valves in a man who was buried by an explosion The sternum was fractured and there was a crushing sensation in the chest with dyspnea as soon as consciousness was regained He lived for rather more than a year when the aortic lesion was confirmed at autopsy Two cases reported by Kissane in 1937 as contusion of the heart showed evidence of damage to the mitral valve Wilks in 1865 recorded the case of a young man who fell from a height striking his left side on a stone He died two days later from peritonitis due to a ruptured bowel Dyspnea had been present but a stethoscope was not used No external bruising was seen at necropsy The posterior cusp of the aortic valves was split transversely but there was no sign of chronic disease of the valves A small deposit of fibrin was found on the rugged edges of the valve Gibson in 1909 recorded a case in the Edinburgh Royal Infirmary of rupture of the mitral valve from the kick of a horse

A sufficient number of similar clinical and pathological findings has been recorded to make this type of valvular lesion a well recognized clinical entity There may be no evidences of external injury The immediate symptoms may be somewhat masked by the blow or other injuries but early distress and signs of a valvular lesion will establish the diagnosis

A more difficult problem is to assess the significance of a history of direct trauma to the chest wall as an etiological factor in a particular case of valvular disease of the heart The well known facts that rheumatic infection may be present with little or no history of its advent and that the aortic valves will become sclerosed from continued strain lead us to accept without question that most cases of valvular disease are due to natural causes Allbutt in 1873 however, described two cases of mitral stenosis in young men in one case due to the kick of a horse and in the other to a blow with a cricket ball The immediate distress at the time was alarming but the heart s function was not distressed soon afterwards to a degree that would indicate rupture of a valve Allbutt saw each patient about a year after the blow and found definite evidence of mitral stenosis which he attributed to trauma Judging by analogy from the proved cases of rupture of a valve it is clear that a blow might produce a contusion with hemorrhage or small tear in a valve which on healing would progress towards chronic valvular disease Where the evidence seems reasonably convincing the diagnosis is justified Bright and Beck in 1935 recorded post mortem evidence of bruising of the interventricular septum

CONTUSION OF THE HEART

1 Pericarditis *When death follows soon after a blow over the pericardium* there may be subpericardial hemorrhage sometimes spreading around the vessels at the base of the heart or perhaps into the mediastinum Unless it is sufficient in amount to hamper the action of the heart, such hemorrhage *will not produce symptoms* Traumatic *pericarditis may* give rise to a friction sound but not necessarily Such a sign is present sometimes when a contusion is probable It is a sign which may have been overlooked in some cases of injury, in which a possible contusion of the heart is considered subsequently

2 Angina Pectoris There are numerous references in medical literature *to angina* pectoris following a blow over the chest In most cases there are disposing causes of age and arterial degeneration White in 1937 states that fatigue of nervous type may dispose towards angina This may be an added factor when litigation is impending Beck in 1935 and Kissane in 1937 *described the syndrome in cases recorded as contusions* of the heart *For convenience angina pectoris following chest injury*

may be discussed under the heading of contusion of the heart but there may not in all cases be structural damage Lewis in 1937 wrote Angina pectoris and cardiac failure never can find equivalents in the terms of structure

As an example of angina of effort the result of direct injury to the chest wall the following recorded case (Barber 1938) is significant because there is no question of compensation The diagnosis is based on what the man himself and his doctor can tell us

> A railway clerk aged 54 years has always had good health On June 4 1937 he tried to jump on to the rear of a lorry which moved He fell heavily onto his left side sustaining a cut head and bruised elbow and hip and his ribs were sore There was no immediate discomfort apart from the bruising but a fortnight later when recovering from this he noticed that when walking briskly for an omnibus he got a gripping pain in the chest radiating down the left arm and he had to stop This discomfort became more frequent and occurred on slight exertion such as climbing stairs so that after doing a fortnight s work he gave it up The heart was recorded as irregular and the rate unduly increased on exertion In August the attacks were less severe but they persisted The pulse was regular He improved but in December would still get angina with moderate exertion On December 7th seen by myself the heart showed no abnormal signs and an electrocardiogram was normal The exercise tolerance was rather poor but he was proposing to go back to his duties which were clerical He did not feel capable of working in his garden

3 Sudden Death A rare but well known occurrence is fatal syncope following a blow over the heart without there being any abnormality detectable at autopsy It is significant in relation to this event that Kissane in 1937 recorded ventricular fibrillation in a dog immediately after an experimental blow with death in 16 minutes This was an isolated event in a number of experiments and had no relation to the force of the blow An autopsy revealed no abnormal lesions Beck in 1935 records ventricular fibrillation with death in two out of 25 experimental contusions

4 Myocardial Injury As an illustration of how the heart muscle may be injured without external signs of bruising there is a case recorded by Groom in 1897 of a boy of 16 who collapsed and died while walking A month previously the shaft of a pony trap pressed him against some railings He lay up for five days There was no external bruising Post

mortem the left ventricle was seen to be ruptured. It appeared to have developed from the endocardium outward.

The absence of symptoms when there must have been a severe contusion of the heart muscle is striking, and this feature is illustrated by Gunewardene's record in 1934 of a boy of nine whose chest was pressed against a wall by the back of a bullock cart. Examined soon afterwards he showed no external injuries, nor evidence of internal ones. He felt well the following day and went to school, where he played the usual games. On the tenth day while playing, he had precordial pain and fell down dead. An autopsy revealed a hemopericardium due to a rupture of the left ventricle.

O'Neill in 1914 described rupture of the heart 47 days after a chest injury, and Fraser (1929, quoting Vaquez Laidlaw), a fatal case of congestive heart failure with post mortem evidence of myocardial injury which had been sustained several months previously. In neither of these patients had myocardial damage been suspected.

If severe contusions which have eventually ruptured into the pericardium may give rise to very little in the way of symptoms the problem of diagnosis is difficult. White in 1937 stated that contusion, or even partial rupture of the heart wall, is probably much more common than has been thought in the past, because of the usual recovery. Sometimes, however, we do get a history and clinical features which are very suggestive of myocardial injury either with or without signs of injury to the chest wall or bones of the thorax.

A lorry driver, aged 40 years, with excellent health, was lifting large blocks of limestone into the lorry. One stone broke and a large piece struck him on the front of the chest and knocked him backwards. He felt a sharp "stitch" above his left nipple, but there was no outward injury. He ceased loading and rested a little, but felt quite well and drove the lorry for several hours. He went to bed apparently all right but woke up with precordial pain, dyspnea, a cold sweat and his legs felt numb. His doctor was called but only recognized a rather weak but regular pulse. He remained in bed seven weeks with some pain and discomfort in the left side of the chest. Seen by myself two months after the accident no abnormalities were detected on physical examination or with radiology or the electrocardiograph. He still complained of a feeling of weight in the chest and inability to exert himself. His exercise tolerance, tested by climbing the stairs, was poor. Six months after the accident he had recovered.

In a case with similar symptoms (Barber, 1938) admitted to hospital on account of a severe blow on the chest there was expectoration of frothy serum for a few days Several electrocardiograms showed no abnormalities

The physical signs of localized myocardial injury will be negligible unless some transient changes in the T wave of the electrocardiogram can be detected Beck in 1935 and Kissane in 1937 have recorded such findings and found them comparable with experimental records from dogs

The symptoms suggestive of myocardial injury following direct trauma of the chest wall are oppression behind the sternum with pain tending to radiate into the left arm dyspnea and perhaps frothy expectoration But it is important to realize that severe myocardial damage may sometimes be attended with very little distress and also that in those cases in which the sternum or ribs are fractured the symptoms tend to be masked Of physical signs we can only look for transient changes in the electrocardiogram which must be sought for early

Typical attacks of coronary thrombosis with characteristic electrocardiogram have been recorded (Beck Wearn 1935) a day or two after a blow over the chest in one case from a golf ball There was a short period of immediate distress followed by recovery and the coronary occlusion developed a few days later

With possibilities so variable it is difficult to assess the prognosis in an individual case or discuss the prognosis question in general There is clinical evidence which is worth noting that it is in the second week after injury that a contusion is most liable to rupture We may accept the teaching that a number of contusions of the heart pass on to complete recovery undiagnosed On the other hand I believe in some cases the heart is inefficient ever after a severe blow on the chest The following record (Barber 1938) is an illustration

> A coal miner aged 50 years Five years ago a steel bar crushed his chest against the roof of a coal mine causing fracture of five ribs on the left side He was three weeks in hospital and three months as an out patient He returned to work but gave up after three days because he was short of breath on exertion and dizzy especially after stooping He has worked for short periods since but has remained short of breath on exertion with some aching in the left side On examination his general

> *condition and muscular tone were good* He was a steady and reliable man of the best type The chest expansion was two and a half inches Radiology showed a heart normal in size with the lungs clear and the ribs united The arteries were healthy The blood pressure was Systolic 115 mm diastolic 75 mm The heart showed no abnormal signs and an *electrocardiogram was normal The pulse rate was 96 on arrival* it was 84 after a short rest after slowly climbing 18 stairs it was 140 and he was short of breath While walking slowly on the flat he was incapable of talking without exhibiting shortness of breath

There is no absolute proof that this man s incapacity is related to his heart but it is probable His general mental and bodily makeup are sound and reliable His limitations do not vary as they tend to in the neurotic or malingerer The condition is not unlike the senile heart but his other tissues are healthy Over a period of about 30 years I have met with five other men in whom I would draw a similar conclusion If the proof of an inefficient heart be accepted it is following the teachings of Lewis in 1937 not to make the attempt to diagnose in the terms of anatomy but in the more certain terms of function

Beck in 1935 described a man of 59 years suffering from cardiac asthma on exertion These attacks were the sequel of a contusion of the heart 16 years previously since when his heart capacity had never been *normal*

It is not possible to describe a definite clinical picture of myocardial contusion but there is evidence as follows

(1) There may be serious myocardial injury with *survival for a* number of days with a few or no symptoms to give warning of a fatal termination

(2) Soon after a blow over the precordium there may be symptoms *which point to injury of the heart muscle of which dyspnea a feeling of* oppression in the chest with perhaps anginal pain and expectoration of frothy sputum are the most characteristic There may be a short interval after the injury before these symptoms develop Proof of structural damage has sometimes been obtained by finding transient electrocardiographic changes Apart from such evidence the symptoms might be explained by hemopericardium or bleeding around the vessels at the base of the heart There may be a pericardial friction sound

(3) A blow over the chest wall may give rise to angina pectoris some form of arrhythmia or to rupture of a valve In some such cases transient

changes in the electrocardiogram have indicated myocardial injury in addition

(4) Coronary thrombosis has developed a few days after a blow over the precordium The blow having caused immediate distress there has been a period free from symptoms till those of occlusion came on

(5) Sometimes long after an injury of the chest there may be evidence of an inefficient heart which is possibly a sequel of myocardial contusion If the sternum or several ribs have been fractured the condition of the heart soon after the accident may have been masked by these injuries

(6) Clinical and pathological evidence proves that the heart may sustain serious structural damage from a blow or crushing injury which leaves no evidence externally nor fractures the sternum or ribs In addition to the evidence already adduced Bilderdeck in 1919 in an adult and Hamilton in 1934 in a child have recorded traumatic rupture of the heart immediately fatal without external injury

(7) The morbid anatomy has shown that anyone of the chambers of the heart may be ruptured as the result of trauma There are a few records of an aneurysm of the heart which has developed at the site of a contusion There does not seem to be any recorded evidence with regard to the post mortem appearance found or sought for in those who appear to have survived a myocardial contusion for a considerable period There are now sufficient clinical records of these cases to make this a practicable study

The treatment of contusion of the heart is chiefly confined to a judicious assessment of the amount of rest indicated The clinical evidence that rupture has been common in the second week is important Bright and Beck in 1935 were of the opinion that the sudden collapse of rupture into the pericardium might be met by operation and suture although they admit that hemorrhage into the pericardium following a contusion of the heart is not always fatal On clinical evidence I think I have seen one survival of this event although the heart efficiency has not recovered completely If there is evidence that the action of the heart is hampered from compression of hemopericardium (see Wounds of the Heart) aspiration of the effusion may be considered

WOUNDS OF THE HEART

Wounds of the heart are caused by needles, cutting instruments and firearms. In civilian life they are met with most frequently in countries where the use of the knife is common. For clinical purposes wounds may be divided into two varieties:

(1) Those in which there is free communication between the pericardium and the pleural cavity or the outside. In such cases, death usually supervenes quickly and the only symptoms and signs are those of loss of blood.

(2) Wounds which give rise to accumulation of blood in the pericardial sac *causing compression of the heart* This may result from a wound which penetrates the heart or from a divided coronary artery. The symptoms of compression, or heart tamponade, are: Shock out of proportion to the loss of blood, a low blood pressure and pulse pressure, with tendency to slow pulse. A cold dusky skin with sweating The external jugular veins are distended; which has significance when the head is elevated. The heart sounds are distant and indistinct. With air and blood in the pericardium there will be a splashing sound The electrocardiograph may not help in diagnosis, although *after* an operation in which a coronary artery has been ligatured, it gives a characteristic picture. There is no pain in this event, however. Wood in 1937 showed that a pericardial effusion may give rise to electrocardiograph changes, particularly characteristic in the T wave of Lead II. The use of chest electrodes is on trial. Occasionally with a pericardium filling slowly radiology may help in the diagnosis Aspiration of blood from the pericardium may help in diagnosis.

In *treatment* the immediate indications are rest, with the foot of the bed raised and perhaps morphia. Saline infusion and adrenalin injections are valuable. Preceded by experiments on animals, surgical suture was practiced successfully towards the end of the nineteenth century, and the technic has been perfected since. Beck in 1926 also Bigger and Porter in 1934 reported successful cases with recovery in a comparatively short time The after history of these does not appear to have been collected as yet.

PRIMARY CARDIAC OVERSTRAIN

There is some diversity of opinion, amongst those best qualified to express it, as to whether the normal heart can be strained. Let us define

the normal heart as one that is efficient for the age and usual activities of an individual and one which would show no abnormality on examination with all the methods at our disposal Price in 1937 defined Primary Cardiac Overstrain as a cardiac disorder which is the immediate result of excessive or injudicious physical exertion in an individual whose heart was previously normal

In a chapter devoted to the subject of trauma of the heart it will be sufficient to confine ourselves to one form of overstrain which is the intense unexpected effort for which a man is not trained and during which the chest is probably fixed with the glottis closed Typical examples in everyday life are a heavy lifting effort or the cranking of a heavy and cold motorcar Sometimes there is impending disaster if the effort should fail so that fear and excitement may arise The following note (Barber 1938) is a typical example

> A man aged 30 was carrying a bag of cement weighing two hundred weight across a stream His foot slipped and he made a very considerable effort to save the bag from falling into the stream which would have ruined the cement He had acute distress in the left side of his chest and collapsed on the ground This was in the middle of the morning He went on doing light work all day suffering from palpitation and shortness of breath He walked home a mile or two very slowly with his father for whom he worked He went to bed and passed a restless night His doctor kept him in bed three or four days after which he got about a little The palpitation and shortness of breath continued to some extent for two years Physical examination at this time showed a pulse rate of about 100 when out of bed with occasional ventricular extra systoles after resting from exertion to which there was poor response He was of good athletic physique Before the event in question he was in excellent health He served four years in the war during which time he won a three mile race without discomfort

My own experience would not suggest that this type of history and sequence is of frequent occurrence Allbutt in 1909 believed that over stress of effort might end in strain but he taught that for one disability due to strain there are 50 of secondary and incidental derangement On clinical evidence he believed that the heart muscle might suffer from dilatation during exceptional effort with subsequent ill effects sometimes temporary and occasionally more or less permanent

Since that time fluoroscopic examination has proved that the irritable inefficient heart which is the sequel of strain real or alleged

is not dilated but is of normal size But the anatomy of the heart after the event is of less significance than its function In considering the structure of the heart during the effort we may bear in mind the observations of Lewis in 1930 that when the heart is examined under the x ray screen with inspiration held and the glottis closed it is seen to dilate greatly There was abundant evidence that healthy men could perform this test with impunity But although this may be physiological dilatation it might proceed to pathological injury of either structure or function during exceptional circumstances

It is outside the scope of this chapter to discuss the heart reserves in relation to athletic events But it is a reasonable premise to the subject under discussion here to say that in athletic event the heart is the part least likely to break down and strain in athletes is almost confined to those taking part when suffering from some infection White in 1937 stated that heart symptoms or signs that follow industrial strain or accidents are usually of the neurocirculatory asthenia type or are due to aggravation of heart trouble already existing This is in agreement with Allbutt s teaching a generation ago We are faced with the necessity however of trying to assess the significance of the sequence of events which may result from a short intensive effort in the average man Donahue in 1927 in an article entitled Accidents and Heart Disease from the Courts Point of View wrote We do have a great many cases of dilatation of the heart occurring at work while the employee is under some particular strain He is lifting some unusually heavy load or is in rather an awkward position doing heavy lifting when he has dilatation and becomes sick sometimes collapsing immediately The events are as described whether or no we accept dilatation of the heart as the explanation And of course a history exactly similar may be obtained from an effort unrelated to industry When the patient comes under observation later he complains of some palpitation and restlessness particularly at night but chiefly of shortness of breath on ordinary exertion The exercise tolerance is poor There may be premature ventricular contractions A fluoroscopic examination reveals a heart normal in size

There are three reasonable explanations

(1) That he is suffering from the effort syndrome or neurocirculatory asthenia and the alleged strain has drawn attention to the disability As confirmation of this we should expect that the capacity for exertion

would be variable from day to day, and there might be evidences of anxiety neuroses *Sighing is common and characteristic* There may be complaint of general weakness In typical examples the effort alleged to have produced the condition will not have been an exceptional one It is usually taught, however, that the effort syndrome occasionally may follow some exceptional physical effort, and also that in spite of the wisest of treatment, some of the subjects must be warned that they are unsuited for strenuous callings

(2) That he has torn some fibers of the pectoral muscle or strained a costochondral junction to which is added a cardiac neurosis This explanation is given prominence by some of those who hold the view that the normal heart cannot suffer as the result of strain One example (Barber, 1938) characteristic of rupture of pectoral muscle fibers was free from cardiac symptoms the only complaint being persistent pain worse on certain movements for three or four weeks Perhaps if the heart s action had been disturbed as the result of an associated neurosis the diagnosis would have been more difficult But pain which persists is unusual after short intensive efforts Morever, it must be remembered that the type of effort may be one quite unrelated to any chest muscles

(3) That there has been some definite strain of the heart muscle, which has disturbed the function of the heart There may be other structural injury, for example a blood vessel ruptured in the myocardium or on the surface of the heart as the result of *forcible beating* The feature most characteristic of a genuine myocardial weakness is a con sistent nonvarying degree of disability at any particular stage There are no symptoms except on exertion The history of the particular strain alleged and the evidence of any witnesses is of value The past medical history, including the evidence of his own doctor is an important guide That a normal heart should suffer as the direct result of a short intensive effort is an exceptional event but if all the evidence is carefully assessed it seems probable occasionally It is agreed that a diseased heart may suffer ill effects from strain It is sometimes suggested that the older hearts should be separated from the younger in this connection But where is the exact dividing line in age? Or for that matter, have we the knowledge to draw a definite line between the diseased heart and the healthy?

As the sequence of a short intensive effort with the chest fixed and the glottis closed, it is probable that sometimes the effort syndrome may result, sometimes there may be rupture of pectoral muscle fibers with a cardiac neurosis added, but sometimes there may be a genuine overstrain of the heart.

Management and Treatment: Whatever diversity of opinion there may be with regard to the diagnosis of the condition there can be agreement with regard to treatment. With a history of some exceptional effort, a short rest is indicated. There should be reassurance that there is no danger to life, and that the outlook is favorable. If the opinion has been communicated to the patient that there has been dilatation of the heart, it is important to have a fluoroscopic examination at once, to assure him that it is of normal size. After a complete examination it is necessary to institute a carefully graded convalescence. In those industries where *there is a medical adviser to the firm he should share in this management* of the problem. There is a genuine disability whatever be the cause.

TRAUMA OF THE HEART AND COMPENSATION

In the preceding paragraphs the endeavor has been made to discuss trauma of the heart without reference to compensation liability. In this way the evidence may be criticized closely, but with an open mind uncommitted by prejudgment.

As a guide in compensation problems, let us summarize what is proved beyond doubt. Both direct violence and strain of effort may lead to auricular fibrillation or to valvular injury. If the event change the life history of the patient we are absolved, in the main, from deciding the problem as to whether disease was already existing.

There is considerable recorded evidence of contusion of the heart after a blow on the chest; but diagnosis is obscure, and a sequel suggesting myocardial weakness may present a problem difficult to assess.

The most vexed question is whether there may be genuine primary cardiac overstrain following a short intensive effort. Let us regard this as a rare and exceptional event, but one which may sometimes change a man's life history, although probably only for a time. The indication is to give a good prognosis, with early return to work, such as he is able to do. It is usually in the best interests of all concerned to avoid the division of opinion which litigation encourages; because with a definite history

would be variable from day to day and there might be evidences of anxiety neuroses Sighing is common and characteristic There may be *complaint of general weakness* In typical examples the effort alleged to have produced the condition will not have been an exceptional one It is usually taught however that the effort syndrome occasionally may follow some exceptional physical effort and also that in spite of the wisest of treatment some of the subjects must be warned that they are unsuited for strenuous callings

(2) That he has torn some fibers of the pectoral muscle or strained a costochondral junction to which is added a cardiac neurosis This explanation is given prominence by some of those who hold the view that *the normal heart cannot suffer* as the result of strain One example (Barber 1938) characteristic of rupture of pectoral muscle fibers was free from cardiac symptoms the only complaint being persistent pain worse on certain movements for three or four weeks Perhaps if the heart s action had been disturbed as the result of an associated neurosis the diagnosis would have been more difficult But pain which persists is unusual after short intensive efforts Morever it must be remembered that the type of effort may be one quite unrelated to any chest muscles

(3) That there has been some definite strain of the heart muscle which has disturbed the function of the heart There may be other structural injury for example a blood vessel ruptured in the myocardium or on the surface of the heart as the result of forcible beating The feature most characteristic of a genuine myocardial weakness is a consistent nonvarying degree of disability at any particular stage There are no symptoms except on exertion The history of the particular strain alleged and the evidence of any witnesses is of value The past medical history including the evidence of his own doctor is an important guide That a normal heart should suffer as the direct result of a short intensive *effort is an exceptional event but if all the evidence is carefully assessed* it seems probable occasionally It is agreed that a diseased heart may suffer ill effects from strain It is sometimes suggested that the older hearts should be separated from the younger in this connection But where is the exact dividing line in age? Or for that matter have we the knowledge to draw a definite line between the diseased heart and the healthy?

As the sequence of a short intensive effort with the chest fixed and the glottis closed it is probable that sometimes the effort syndrome may result, sometimes there may be rupture of pectoral muscle fibers with a cardiac neurosis added but sometimes there may be a genuine overstrain of the heart

Management and Treatment Whatever diversity of opinion there may be with regard to the diagnosis of the condition there can be agreement with regard to treatment With a history of some exceptional effort *a short rest is indicated There should be reassurance that there is no* danger to life and that the outlook is favorable If the opinion has been communicated to the patient that there has been dilatation of the heart it is important to have a fluoroscopic examination at once to assure him that it is of normal size After a complete examination it is necessary to institute a carefully graded convalescence In those industries where there is a medical adviser to the firm he should share in this management of the problem There is a genuine disability whatever be the cause

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of exceptional effort and a heart disturbed in function the disability is a real one

Those heart lesions of which there are only a few recorded examples following trauma must be considered carefully as individual problems

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CHAPTER XVI

ACUTE PERICARDITIS

By William B. Porter, M.D.

Definition: Acute pericarditis is acute inflammation of the pericardium, and the reaction in this structure is invariably an integral part of a *systemic disease, a septicemia* or an *inflammatory extension* to the pericardium from contiguous diseased tissues or organs.

ETIOLOGY AND CLASSIFICATION

Acute inflammation of the pericardium results in two basic types of reaction: Serofibrinous (pericarditis sicca); and serous, serosanguinous, or purulent exudation in the pericardial sac (pericarditis with effusion). Acute pericardial disease should not be considered an independent entity, but rather a part of a systemic malady, the pericardial involvement denoting an additional somatic reaction. The nature of the specific etiologic agent is largely responsible for the severity and character of the pericardial reaction; yet, the state of the patient at the time of the invasion of the pericardium and the condition of the adjacent structures are factors which influence in no small degree the gravity of the inflammatory process.

It is highly desirable, therefore, to have as a basis for approach to the clinical problems of acute pericarditis a classification of a different order from that which is founded upon the nature of the pericardial inflammatory reaction. The following classification gives one the proper perspective since the type of pericarditis is immediately related to the associated disease and this orientation logically suggests a concise and rational foundation for prognosis and treatment:

A. Rheumatic pericarditis (rheumatic fever).

B. Bacterial pericarditis:

(*a*) Tuberculous.

(*b*) Pyogenic:

1. Pneumococcus.
2. Streptococcus
3. Staphylococcus.
4. Colon bacillus.
5. Gonococcus.
6. Bacillus melitensis
7. Bacillus tularense.
8. Bacillus influenzae.

C. Nonbacterial:
 (a) Myocardial infarction.
 (b) Uremia:
  1. Chronic glomerulonephritis
  2. Malignant nephrosclerosis.
 (c) Trauma.

PATHOLOGIC ANATOMY

Acute pericarditis, rheumatic and bacterial, begins as a serofibrinous reaction, accompanied by myocarditis of varying quality and intensity Tuberculous pericarditis is an exception for the myocardium is rarely, if ever, diffusely involved; yet, encapsulated tubercles are occasionally found in the heart muscle.

At the onset the process may be localized and may involve only one layer of the pericardial sac, but it quickly involves the entire heart surface and the parietal pericardium. The deposited inflammatory exudate varies greatly in amount, sometimes being as heavy as 0.5 to 1.0 cm in thickness. Because of the constant movement of the heart, the exudate assumes a stringy or shredded appearance, giving the pericardial surface a villouslike architecture.

In tuberculous and rheumatic pericarditis varying amounts of serous *or serohemorrhagic exudates are formed, the quantity varying from a few* cc. to 3000 cc. The effusion which occurs in pyogenic pericarditis is purulent in character, yet, the degree of purulence varies greatly

Localized effusions occasionally occur. The writer recently has studied a patient with tuberculous pericarditis who had an effusion localized over the right auricle and part of the right ventricle The roentgenogram had many features suggesting a large aortic aneurysm, and the clinical picture was quite similar to the syndrome of constricting pericarditis. Uremic pericarditis and the localized pericarditis overlying *an acute myocardial infarction are relatively insignificant in their gross*

aspects in comparison with rheumatic and bacterial pericarditis These lesions are noninfectious in nature and are probably never accompanied by effusions unless secondarily infected

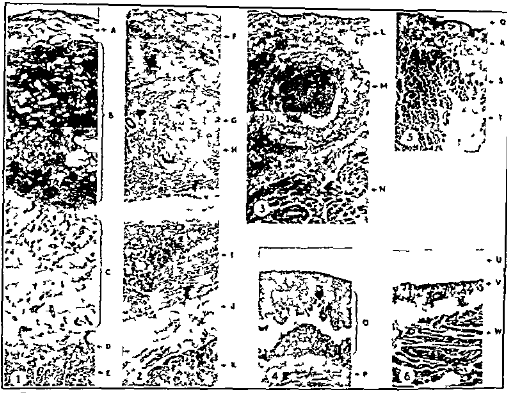


FIGURE 1 Rheumatic pericarditis × 60 *A* Partial organization of fibrin layer Surface zone. *B* Dense layer of fibrin *C* Granulation of epicardial fat tissue *D* Adjacent epicardial inflammatory infiltration *E* Myocardium

FIGURE 2 Tuberculous pericarditis × 60 *F* Dense granulation tissue *G* Characteristic tubercle *H* Typical giant cells *I* Granulation tissue *J* Epicardial fat tissue layer *K* *Myocardium (no inflammatory infiltration)*

FIGURE 3 Acute pyogenic pericarditis × 80 *L* Acute inflammatory infiltration *M* Septic embolus in coronary vessel *N* Acute inflammatory infiltration of myocardium

FIGURE 4 *Uremic pericarditis × 60 O Noninflammatory hyaline layer P, Epicardial* connective tissue

FIGURE 5 Myomalacic pericarditis × 60 *Q*, Layer of fibrin *R* Moderate round cell infiltration of epicardium *S* Degenerating swollen muscle cells *T* Recent myomalacic area

FIGURE 6 Normal epicardium × 60 *U* Serosal membrane (single cell layer) *V* Epicardial fat tissue *W*, Myocardium

PATHOLOGIC HISTOLOGY

Rheumatic Pericarditis Although not specific, rheumatic inflammatory changes in the epicardium and pericardium are rather characteristic in that there is a granulation type of inflammation extending into the myocardium and to the outer surface of the epicardium This reaction appears *to start from foci of rheumatic cells in the interstitial tissue of the*

myocardium and to spread progressively throughout most of the epicardium The fat layer is entirely granulated with increased numbers of vessels and round cell infiltration Superimposed on this there is a thick layer of dense fibrin which shows characteristic staining reaction Again the extreme peripheral zone and surface show moderate granulation favoring the formation of rather extensive adhesions which later organize and become dense Typical Aschoff bodies may or may not be found When present they are characteristic but their absence does not exclude the rheumatic nature of this type of pericarditis (Fig 1)

Tuberculous Pericarditis The only truly specific inflammatory change of the epicardium and pericardium is seen in the tuberculous type Characteristic tubercles with epithelioid cells and subsequent hyalinizing fibrosis and the scattered giant cells are almost always present The myocardium and immediate epicardial layer of fat are frequently if not always found to be free of involvement the epicardial fat layer often being rather thick The actively granulating outer surface of the inflammatory tissue which is more vascular and in which fibroblasts are proliferating greatly favors the formation of adhesions which may become generalized and dense (Fig 2)

Pyogenic Pericarditis A localized phlegmonous type of polymorphonuclear acute inflammatory infiltration characterizes the changes involving any focal regions of the epicardium and the surrounding adjacent structures This type of reaction is found particularly where a small infected embolus occludes or partially obstructs a surface coronary vessel There follows an acute arteritis periarteritis and an inflammatory infiltration of the interstitial tissue of the adjacent myocardium and epicardium From this focus a generalized purulent inflammation spreads over the entire pericardial sac In acute bacterial endocarditis purulent pericarditis frequently results in this manner In other instances the pericarditis is an extension to the pericardium from purulent foci in the lungs mediastinum or peritoneum Less frequently it is a part of a bacteremia or a metastatic invasion from a distant focus such as staphylococcic osteomyelitis (Fig 3)

Uremic Pericarditis The highly characteristic change in this type of involvement of the pericardium and epicardium is the absence of inflammatory cell infiltration The myocardium is free and the epicardial tissue shows no inflammatory change Superimposed upon the surface of

the epicardium, there is a layer of varying thickness, made up of an eosinophilic, homogeneous *material which does not take the character* istic fibrin stains Histologically it appears to be, and the tinctorial characteristics are those of a protein precipitate No underlying myo cardial damage is histologically demonstrable The absence of granula *tion and other inflammatory* reactions exclude the probability of the formation of fibrous adhesions (Fig 4)

Myomalacic Pericarditis It *is probable that whenever a patch of* myomalacia occurs near the surface or at the surface zone of the myocar dium, there is a reaction of a mild inflammatory nature involving the immediate adjacent epicardium This reaction is usually characterized by some edema a mild round cell infiltration and perhaps engorgement of the small capillaries in the epicardium The epicardial fat tissue is involved when present in a thin layer The surface of the epicardium is covered with a thin layer of dense fibrin, which takes characteristic fibrin stain, and thereby covers whatever slight granulation may be present However, a chronic inflammatory granulation tissue is not fre quently found This epicardial inflammatory process tends to spread laterally from the origin of myomalacia and may involve a larger area of epicardium than is represented by the underlying malacic patch The absence of typical granulation tissue reaction apparently protects the epicardium from adhesions (Fig 5)

SYMPTOMS

Acute pericarditis may exist without the addition of any subjective complaints distinct from those common to the primary disease but there are two circumstances which give rise to new symptoms

1 When there is concurrent inflammation of the pleura and this complication is frequent pain results It is usually sharp in character intermittent or continuous is frequently aggravated by respiration and the area of distribution is variable being at times only remotely related to the pericardial area The pain is felt most frequently over the left anterior thorax but, at times it is distributed to an area of the abdomen supplied by the left lower intercostal nerves producing symptoms which closely simulate acute intraabdominal disease Pain in the left supra scapular area may be distressing when the central zone of the diaphragm

is involved, and interscapular pain and hyperesthesia occur when there is an associated posterior mediastinitis

It is an interesting observation that uremic pericarditis is not complicated by pleuritis and pain is never a symptom

2 The symptoms other than pain occurring in the clinical course of acute pericarditis *are the result of pericardial effusion* *These are, in the* main, due to the degree of intrapericardial pressure and to the physical compression of the extrapericardial contiguous structures, and these effects, in turn, are dependent upon the rate of formation and quantity of the effusion A small effusion may produce no symptoms, whereas, a moderately large effusion (500 cc) which has accumulated rapidly compresses the auricles, vena cava and hepatic veins, seriously interfering with cardiac filling and results in a diminished minute volume of circulating blood to the lungs and systemic arteries Thoracic distress, dyspnea tachycardia, reduced systolic and pulse pressure, elevated venous pressure *(distention of the cervical veins), and an enlarged tender liver ensue* The similarity of the symptoms and altered circulatory dynamics to those occurring in congestive heart failure frequently results in the erroneous diagnosis of primary myocardial insufficiency. Large effusions result in the same type of respiratory and cardiovascular symptoms, but they are as a rule, of greater severity, and there are added extrapericardial compression symptoms Cough cyanosis, dysphagia and hoarseness Patients *having large effusions* with high degrees of *intrapericardial pressure* masquerade with the clinical picture of advanced congestive heart failure A large tender liver, extensive edema, markedly distended jugular veins and orthopneic *posture with the head bent forward in an effort to relieve* the distressing breathlessness

The temperature changes, sedimentation rate and hematopoietic deviations conform to those common to the primary disease, and are not materially altered in degree or character by the additional inflammatory reaction in the pericardium However, tuberculosis of the pericardium is a notable exception for a moderate leukocytosis is usual in serous mem*brane tuberculosis,* and not in uncomplicated pulmonary or glandular lesions of a similar etiology

PHYSICAL SIGNS

The diagnosis of acute pericarditis, without the aid of roentgen rays, is dependent upon the detection of those phenomena caused by the

fibrinous exudate or by the accumulation in the pericardial sac of an effusion sufficient in quantity to be clinically detectable

The detection of a to and fro friction rub over the precordial area is sufficient evidence to warrant the diagnosis of fibrinous pericarditis It is usually plainly audible and its intensity is increased by pressure of the bell of the stethoscope and by expiration This phenomenon is pathognomonic evidence of pericarditis sicca but must be searched for at frequent intervals for often it can be heard for only a brief period of time This sign may have a superficial resemblance to an endocardial murmur but error in interpretation is not probable if due consideration is given to the established points in differential diagnosis Once the existence of pericardial friction is established its significance must be interpreted as indicating a fibrinous pericarditis but it should not negate the diagnosis of pericardial effusion All too frequently the heart fills the space between the sternum and spine and will remain against the pericardial sac in the presence of large effusions And again if the fluid distends the pericardium posteriorly as it so frequently does it tends to force the heart anteriorly against the chest wall A pericardial friction signifies pericarditis which implies that an effusion may either be in the making or existing at that time in large quantities

The physical phenomena which are caused by distention of the pericardial sac by an effusion may be profitably discussed under two subdivisions

I Signs which are the result of the enlarged pericardial sac and

II Those which result from cardiac tamponade

I Signs Which Are the Result of the Enlarged Pericardial Sac

(*a*) An increase in the supracardiac dullness in the second and third interspaces especially to the left of the sternum This is an early sign of effusion elicited by light percussion with the patient in a recumbent position and the extent of the dullness lessens or disappears when the patient sits up

(*b*) An extension of the left line of cardiac dullness beyond the palpated apex thrust a high area of left auricular dullness and an increased area of absolute cardiac dullness

(*c*) Evidences of consolidation in the left lower lung lobe or atelectasis of this lobe (Ewart s sign) These posterior phenomena assume one of two rather distinct types

1 Distant bronchial breathing with impaired resonance at the angle of the left scapula With large pericardial effusions these findings increase involving the entire left lower lobe posteriorly closely imitating a pneumonic consolidation

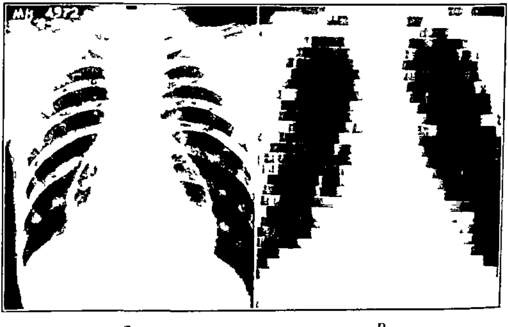
2 The physical phenomena of pulmonary consolidation plus those of a pleural effusion These signs at times are so strikingly similar to those produced by a pleural effusion that not infrequently a pericardial sac is aspirated posteriorly under the belief that pleural effusion is present It is obligatory therefore that some distinctive differential point be found to aid in the clinical separation of pericardial effusion and pleural effusion when these elusive phenomena are present With this object in mind a careful note has been made of the upper margin of percussion dullness in patients with pericardial effusion and in whom the diagnosis has been conclusively made This line reaches its maximum height at the angle of the scapula descends downward in the axillary zone reaching the lowest point in the midaxillary line then rises to become continuous with the left margin of pericardial dullness An analysis of this line of dullness shows it to be a reversed Ellis S shaped line observed in pleural effusion the major difference being the absence of axillary flatness consistently found in free pleural effusions The inverted S line has proven to be invaluable in differentiating pericardial effusion from pleural effusion when there existed in the area of the left lower lung these confusing phenomena due to pulmonary atelectasis

(*d*) The changes in the cardiac roentgenogram produced by a pericardial effusion are most distinctive for the size and shape of the cardiac shadow and amplitude of contraction can be observed with a degree of accuracy not possible by any other physical method The roentgenograms should if possible be made in both the recumbent and sitting postures which will record the changes in shape resulting from the effect of altered posture on the distribution of the pericardial effusion

The fluoroscope is peculiarly valuable for studying the amplitude of cardiac contraction for the contraction waves progressively lessen as the intrapericardial pressure rises This rise is at times so great that a picture approaching a dead heart results

A B

FIGURE 7 A Teleoroentgenogram Tuberculous pericarditis with effusion B Kymographic teleoroentgenogram Same case and taken at same time as Fig 7A showing undulating waves and no muscle contraction waves



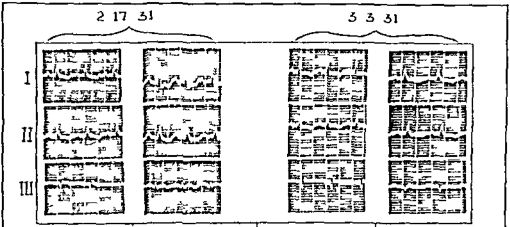
C D

FIGURE 7 C Teleroentgenogram Same case as Fig 7A after aspiration and the introduction of 300 cc. of air D Kymographic teleroentgenogram Same case and taken at same time as Fig 7C

A new method the kymograph is designed primarily for studying the amplitude and character of the heart s contracting waves (Fig 7a b c d) It is an ingenious apparatus but it is doubtful whether it gives more useful data than a careful fluoroscopic study

II Those Which Result from Cardiac Tamponade

(*a*) With the development of pericardial effusion there is a rise in venous pressure *The degree of venous hypertension is dependent upon*



Before Aspiration 10 30 AM Venous Pressure 185mm H_2O Blood Pressure Sys 85 Dias 62 Pulse Rate 125	After Aspirating 1250 cc of Exudate 11 10 AM Venous Pressure 35mm H_2O Blood Pressure Sys 118 Dias 76 Pulse Rate 136	Before Aspiration Venous Pressure 165mm H_2O Blood Pressure Sys 98 Dias 70 Pulse Rate 125	After Removal of 900cc of Exudate Venous Pressure 45mm H_2O Blood Pressure Sys 122 Dias 75 Pulse Rate 132

FIGURE 8

the rapidity of development and volume of the pericardial effusion The elevated venous pressure results in distention of the neck veins above the level of the right auricle enlarged and tender liver and if this state continues widespread edema and ascites

(*b*) *With the rising intrapericardial pressure* there results a fall in systolic and pulse pressure and an increase in pulse rate The changes in blood pressure may be interpreted as indicating a reduction in stroke volume the result of cardiac tamponade and the reduced aortic pressure

initiates a sinus tachycardia to offset the effects of reduced stroke volume on the minute volume of circulating blood. The compensation is rarely complete for many of the symptoms observed in large pericardial effusions can best be explained by a reduced minute volume of circulating blood ("forward failure") rather than the venous stasis.

(*c*) Pulsus paradoxus This phenomenon is observed in pericardial effusion, but it occurs in other cardiac and pulmonary diseases, and this fact greatly lessens its diagnostic significance.

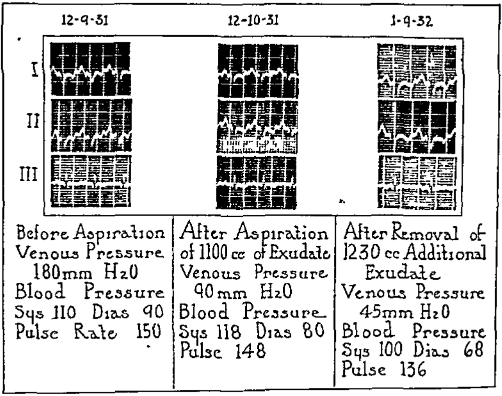


FIGURE 9

ELECTROCARDIOGRAM

The changes which occur in the electrocardiogram consist of an elevation of the R T segment and varying degrees of inversion of the T wave. If electrocardiograms are made at frequent intervals, these changes will be found in a large percentage of patients who have rheumatic or bacterial pericarditis. The earlier writers concluded that the deviations occurring in the electrocardiogram were attributable to reduction in coronary blood flow resulting from the effects of the pericardial effusion

on the coronary circulation Figures 8 and 9 which are selected from many similar experiments strongly suggest that the intrapericardial pressure is not concerned in the pathogenesis of the R T changes in the electro cardiogram Recent studies have definitely proven that the observed changes occurring in acute pericarditis are due to alterations in the myocardium adjacent to the inflammatory reaction in the pericardium This conclusion is in harmony with the established facts relative to R T deviations

CLINICAL PROBLEMS PECULIAR TO SPECIFIC TYPES OF PERICARDITIS

Rheumatic Pericarditis The clinical behavior of rheumatic fever is no index to the probability of pericarditis Rheumatic serofibrinous peri carditis is not unusual in patients in whom the joint phenomena are so mild that they are entirely ignored by the individual The acute exuda tive types of rheumatic polyarthritis occur infrequently in the southern clinics yet rheumatic fever is a most important cause of acute and chronic pericardial disease in these areas *Pericardial effusion is a com mon complication of rheumatic pericarditis, however it rarely if ever occurs in sufficient volume to warrant aspiration* Exploratory puncture should be resorted to with the utmost caution no cases in which sub sequent events have shown that it would have been justifiable have come under my notice (Coombs) Pericardial adhesions localized and general are end results of acute rheumatic pericarditis It is doubtful however if these healed lesions have any effect *per se* upon the heart unless the thickened pericardium impedes normal venous return to the right auricle or lessens cardiac diastole

Tuberculous pericarditis occupies a unique place in any study dealing with either tuberculosis or cardiac disease It occurs occasionally as a part of multiple serous membrane tuberculosis or of miliary tuber culosis but more often it results from caseous mediastinal lymph glands or clinically quiescent pleural or pulmonary foci which justifies the term primary pericardial tuberculosis (Reisman)

The clinical course of tuberculosis of the pericardium is both elusive and variable and is therefore frequently confused with other diseases

Those cases presenting the symptoms and signs of massive pericardial effusion may be confused with heart failure when prolonged subacute

tamponade has resulted in extensive edema enlarged liver and pulmonary congestion yet the probability of error is remote if reasonable care is exercised On the other hand the proliferative types of tuberculous pericarditis may be easily mistaken for coronary insufficiency with progressive heart failure hepatic cirrhosis or an obscure febrile wasting disease At least 80 per cent of all patients who have tuberculosis of the pericardium are more than 40 years of age which fact alone adds greatly to the likelihood of confusing the clinical syndrome with a degenerative cardiovascular or hepatic disease

Pyogenic or purulent pericarditis must be recognized early if treatment is to be successful As in other forms of acute pericarditis the onset may not cause any symptoms peculiar to the disease of which it is a complication however when a patient suffering with acute osteomyelitis empyema pulmonary suppuration or suppurative peritonitis continues ill though adequate drainage has been accomplished purulent pericarditis should be looked for as a possible complication The development of cardiac distress and breathlessness with the symptoms of sepsis demands a careful search for the physical phenomena of pericardial effusion and repeated roentgenologic studies should be made There are diverse opinions as to the relative value or danger of a diagnostic paracentesis pericardii in suspected pyopericardium It is the only way to make a complete diagnosis and if properly performed the implied dangers are unimportant in comparison with the value of the procedure

During the terminal stage of chronic glomerulonephritis and the malignant phase of essential hypertension pericarditis sicca frequently develops when renal insufficiency becomes absolute and there is nitrogen retention A localized fibrinous pericarditis occurs with acute coronary thrombosis when the infarcted area extends to the surface of the myocardium Neither of these types justifies more than casual consideration in a discussion of acute pericarditis for they are not infectious in origin and in no way alter the clinical course of the primary disease

DIFFERENTIAL DIAGNOSIS

The existence of acute pericardial disease may be entirely unsuspected because of the predominance of the primary disease or the absence of the usual symptoms and signs of pericardial inflammation

The diagnosis of fibrinous pericarditis offers no difficulties when the characteristic friction rub is heard. This phenomenon may conceivably be confused with a harsh endocardial murmur, but such error is not *probable if due consideration is given to the established points of* differentiation.

Cardiac dilatation and pericardial effusion do at times have a superficial similarity. The history of the illness is most helpful for the causes of cardiac dilatation are distinctive and quite different from those occurring *in patients with acute pericarditis. During the course of acute* rheumatic carditis, cardiac dilatation is occasionally complicated by pericardial effusion, and this combination is almost impossible to distinguish from an uncomplicated large effusion. The problem does not introduce serious difficulties for the reason that *it is doubtful whether one is ever justified in assuming that effusions accompanying rheumatic pericarditis require aspiration.*

The differentiation of coronary insufficiency with progressive and irreducible congestive failure from the proliferative types of tubercular pericarditis is difficult at times when the thickened pericardium obstructs the hepatic veins and vena cavae. Fever, inspiratory filling of the neck veins, enlarged cardiac area with a feeble or absent apex beat and an absence of gallop rhythm favor pericardial disease. A careful roentgenologic study adds greatly to the accuracy of the differential diagnosis.

Acute pericarditis causes at times very confusing abdominal symptoms so perfectly simulating acute inflammatory lesions in that area that useless operations for suspected surgical diseases are too frequently done. This error will be avoided *if due consideration is given to the entire clinical* history and the thoracic structures are skillfully investigated in the differential diagnosis of atypical acute abdominal syndromes.

TREATMENT

The occurrence of acute pericarditis in the course of a disease may not introduce any problems requiring a modification of the therapeutic régime already in progress. *It is particularly true of the types occurring* in the course of rheumatic fever, uremia and coronary thrombosis that the treatment of the primary disease is the first consideration. Acute pericarditis occurring in rheumatic fever indicates, however, extensive

cardiac involvement, and for this reason the duration of treatment of the primary disease is lengthened

Regardless of the type of pericarditis, thoracic distress and pain are at times prominent symptoms and require therapeutic control A lightly filled ice-cap placed over the precordium frequently gives considerable comfort and should be tried routinely As a rule, the use of opiates is indicated and required Morphine sulfate not only relieves pain but promotes sleep and lessens the patient s anxiety which is at times distressing

There are three situations arising in the course of acute pericarditis which require special consideration

1 The development of pericarditis during the course of any disease *caused by one of the pyogenic bacteria* requires great vigilance on the part of the attending physicians Modern surgical treatment combined with the use of repeated transfusions and the sulfanilamide derivatives have reduced the mortality of purulent pericarditis to less than 40 per cent It is possible that this figure will greatly lessen with more experience in the use of this combined surgical and chemotherapy regime Every effort must be made to determine the existence of purulent effusion at the earliest possible moment by the use of a diagnostic puncture guided by careful roentgenologic study If the pericardial effusion is found to be purulent immediate surgical drainage is indicated

2 *When pericardial effusion causes symptoms which can* be interpreted as indicating cardiac tamponade or compression of lung tissue to an extent that vital lung capacity is seriously reduced, pericardiocentesis must be promptly done though only a few hundred cc are aspirated

3 Tuberculous pericarditis is an individual problem In all types the established therapeutic principles for active tuberculosis must be rigidly adhered to in an effort to arrest the active lesions When effusion occurs, it invariably accumulates in large quantities and repeated aspiration is required There is some merit in introduction of air into the pericardial sac after withdrawing as much fluid as can be aspirated without unduly disturbing the patient The amount injected is varied by different workers but 150 cc is a conservative average It is difficult to evaluate the therapeutic results reported from the use of artificial pneumopericardium however, the evidence is decidedly favorable and there do not appear to be any valid contraindications

Tuberculous *pericarditis is a serious disease,* yet, *many cases do go* unrecognized and recover *spontaneously; and the type with serous* effusion, if adequately treated, appears at times to recover with slight disability.

Pericardial Paracentesis: Pericardial aspiration should never be attempted until the site selected for the puncture has been adequately anesthetized with 0.5 per cent novocain solution. It is desirable to use a No. 27 needle to infiltrate the skin and the chest wall, including the pleura, and sufficient time must be allowed for the anesthetic to take effect before the exploratory needle is inserted. If the patient is distressed *by pain, breathlessness and anxiety, the procedure should be* preceded by morphine sulfate administered hypodermically.

The aspirating needle should be either No. 18 to No. 16 gauge size and have a short point. A 30 cc. glass syringe is a convenient size, which is best attached to the needle by a piece of rubber tubing, 4 cm. in length, which allows some movement of the needle if it comes in contact with the heart. The selection of the point for introducing the needle requires much judgment, for it must be appreciated that there is no single area suitable to every patient. A careful study of the anteroposterior and *oblique teleoroentgenograms aids greatly in the selection of the most* desirable area. It will be found that 1 to 2 cm. outside of the apex beat in the fifth or sixth intercostal space is the area of choice in the majority of patients requiring pericardial aspiration. The area next in importance is the point formed by the junction of the ensiform appendix and the left costal arch. When this point is chosen, the patient's body should be elevated 30 to 40 degrees and the needle directed slightly upwards. The *epigastric site is particularly desirable when there is a* large effusion, and it is desirable to empty the lower part of the pericardial sac. When the effusion projects unusually far to the right, the needle may be inserted in the fourth intercostal space 1 cm. to the right of the sternum. In the rare case where fluid is not obtained from either of the anterior sites and there are well developed posterior compression phenomena *(Ewart's sign), the needle may be inserted in the seventh or* eighth intercostal space in the mid-scapular line with the left arm raised to lift the scapula upward and outward from the site of puncture. This site for paracentesis should not be chosen if purulent pericarditis is sus-

pected for the danger of pleural infection by the contaminated needle is great

Regardless of care used the heart is occasionally felt against the trocar and the ventricular wall may even be perforated without harm but injury to a coronary artery may be serious This fact emphasizes the importance of assuring a patent lumen by the use of a stilet when no fluid is aspirated at a reasonable depth and in the choice of a needle with a short beveled point

CHAPTER XVII

CHRONIC CONSTRICTIVE PERICARDITIS

(Also Called Pick's Disease, Concretio Cordis, and Chronic Compression of the Heart)

By Paul D. White, M.D.

Definition: Chronic constrictive pericarditis is a disease consisting primarily of obstruction to the diastolic filling of the heart because of the presence of dense, unyielding, chronically diseased pericardium.

Sometimes called by the unsatisfactory designation *"Pick's disease,"* this malady has become a subject of increasing interest and importance during the past few years. The reasons for this are two. In the first place, the condition has been one easily mistaken for something else, and, secondly, it is now possible in certain cases to effect a cure by proper treatment, whereas in the past there was no adequate treatment and the disease was regarded as hopeless and necessarily carrying with it years of invalidism.

ETIOLOGY AND PATHOLOGY

Chronic constrictive pericarditis always follows acute pericarditis, which may or may not itself be constrictive. Sometimes it is possible to follow the course of the case from the beginning of the acute pericarditis right through to the stage of chronic constrictive pericarditis over a period of months to years. In a good many cases, however, it is impossible to make such an observation, the acute pericarditis having been very insidious and frequently undiagnosed.

The majority of the patients are young (children or young adults), but the disease may appear in middle age. Both sexes are affected. In the writer's series of 28 cases, 19 were male and 9 female. The ages (in years) at which the disease became manifest were as follows: 5½, 7, 10, 12, 12, 14, 17, 17, 21, 23, 23, 25, 27, 27, 27, 30, 31, 32, 32, 34, 38, 39,

42, 42, 41, 45, 50, and 51. Thus, there were only 5 of the 28 cases in whom the disease became apparent after the age of 40; it is preponderantly the result of infection in youth and commoner in males.

As a rule, the thickening of the pericardium consists of a fibrosis, the cause of which is undeterminable at the time of histological examination. Simply evidence of the result of inflammation is found, without definite indication of the cause of such inflammation. In a few cases, tuberculosis is discoverable; in a few other cases, some septic infection; and in still other cases, a reaction associated with polyserositis attending a pneumonia or other infection In most instances the etiological factor is unknown or obscure. In only very rare cases is rheumatism even a possible causative factor. In the series of 28 cases observed by the writer at the Massachusetts General Hospital (proved by operation or otherwise), rheumatism has been the cause in no case.

The pericardial sac may or may not be obliterated; usually it is. It is to be recognized at the outset that obliterative pericarditis is not synonymous with chronic constrictive pericarditis, since most obliterative pericarditis does not constrict the heart, at least to any serious degree. Both layers of the pericardium may be much thickened to cause the constriction, or either layer, epicardium or parietal pericardium or both; may be so firmly adherent that it is impossible to separate them or to distinguish which is the more thickened. The thickening of the pericardium may be universal or only over certain parts of the heart. In order to have the important constricting effect, however, the amount of pericardium involved is usually considerable. The posterior surface of the heart, *i. e.*, over the left ventricle and left auricle, is generally less involved than the anterior surface, *i. e.*, over the right ventricle and right auricle. The great vessels may or may not be constricted at their junction with the right auricle. There may or may not be fluid in the pericardium in addition to the thickening. When fluid is present in the pericardium, the constriction may be due more to the fluid than to the chronic thickening of the pericardium itself, such a state is not strictly to be designated chronic constrictive pericarditis, since nearly all fluid accumulations occur during acute or subacute involvement of the pericardium, and should be classed under the designation *acute* or *subacute constrictive pericarditis (cardiac tamponade)*.

Calcification may be superimposed as a complication in chronic pericarditis It has been present in about one third of the writer s cases But, again there must be a clear differentiation between calcification of the

FIGURE 1 Heart encased in constricting pericardial sac, Note the fibrosed pericardium as thick as shoe leather (Courtesy of the Lancet London)

pericardium and chronic constrictive pericarditis There may be either without the other

Polyserositis (sometimes called *Concato's disease*), has at times erroneously been regarded as synonymous with chronic constrictive pericarditis To be sure chronic polyserositis is frequently found with chronic constrictive pericarditis and acute polyserositis may precede

chronic constrictive pericarditis but again either may be present without the other

Perihepatitis (frosted or iced liver or Zuckergussleber) and perisplenitis belonging to a chronic peritonitis may be a part of a polyserositis but they have sometimes been incorrectly attributed to chronic constrictive pericarditis itself

Finally thick external adhesions binding the heart to the chest wall may or may not complicate chronic constrictive pericarditis They are not part of the picture although it is usual for the heart to be adherent to the diaphragm

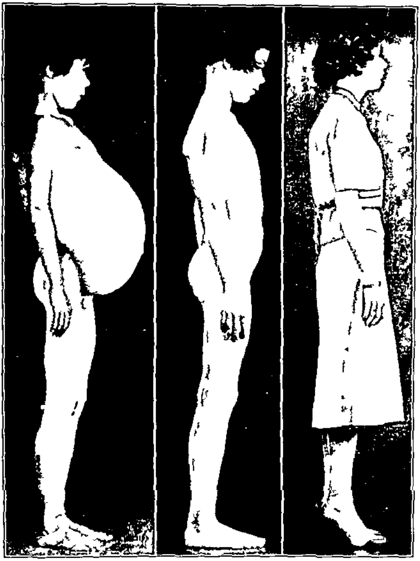
DIAGNOSIS

No one finding is conclusive for the diagnosis of chronic constrictive pericarditis Use must be made of the assembly of all available information including history physical examination and laboratory data particularly electrocardiography and x ray study

Probably the most important diagnostic clue of all is the development in a young or middle-aged individual of evidence of increase in the systemic venous pressure consisting of engorgement of the neck veins enlargement of the liver dependent edema and actual increase in direct venous pressure (above 10 cm of blood or water) in the absence of evidence of heart disease and provided acute pericarditis with effusion is not the cause That is the slow onset of dropsy particularly evidenced by enlargement of the abdomen should cause suspicion of the diagnosis Liver enlargement alone is not indicative of the condition because there are many other causes for a big liver Liver enlargement and evidence of increased systemic venous pressure are suggestive of the condition but *heart disease with failure is the common cause of such findings* and these must be ruled out at the start The ascites that is so frequently present is in large part merely secondary to the liver enlargement

It is true that increase in the size of the abdomen due to enlargement of the liver and ascites is predominant and often one of the earliest signs but there are exceptions to this rule Sometimes the edema first appears in the feet and sometimes the edema of the legs is at least as great in degree as the enlargement of the liver and ascites This variation is probably due to the variability of the relative increase in pressure in the hepatic veins and in the inferior vena cava There is also sometimes slight edema of face chest wall or arms especially after recumbency

It is of great importance and help in the diagnosis to have had a clear history of acute pericarditis with friction rub or effusion preceding the signs and symptoms of chronic constrictive pericarditis by months or years



A *B* *C*

FIGURE 9 (Case A) *A* Ten years old showing the marked ascites engorged neck veins and malnutrition characteristic of advanced chronic constrictive pericarditis *B* Same case two years later six months after surgical cure *C* After another six years still showing a normal state of the circulation

Other signs that are helpful in establishing the diagnosis are a small arterial pulse pressure with a tendency to the so called paradoxical pulse (a sharp decrease in systolic and pulse pressure during inspiration) and

the tendency for the heart to remain fixed in its position during respiration and change in position of the body. *It is possible, however, to have* the heart chronically constricted by a thickened pericardium while it remains completely or almost completely mobile, due to the fact that

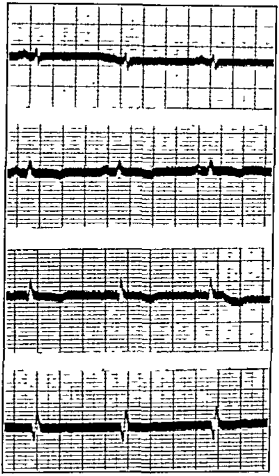


FIGURE 3. Electrocardiogram (Leads I, II, III, and IV) from typical case of chronic constrictive pericarditis (Case B), showing low voltage of QRS waves and abnormal (flat or inverted) T waves.

there are no important external adhesions. Broadbent's sign is gen erally absent.

The size of the heart may be normal or slightly to moderately increased; it is never markedly increased when an uncomplicated case is dealt with, and most of the cases are uncomplicated. There are no important murmurs, although systolic murmurs at the apex are not rare. There is frequently a loud third sound in early diastole, heard best at the

FIGURE 4 X ray picture (teleoroentgenogram) of heart and pericardium of case of chronic constrictive pericarditis with calcification (Case C) Note the shell of calcium just outside the shadow of the left heart border and along the diaphragmatic border

a subacute pericardial or polyserositic infection or some other complication must be suspected The serum protein may or may not be reduced, it is reduced in severe cases with malnutrition Liver functional tests may or may not show slight reduction, but there is no evidence in uncomplicated cases of severe liver damage There is never any jaundice, or

by Dr Churchill in the last 11 years and ten of these are well and active today (at the end of 1939) the other case having succumbed to pneumonia and empyema a year after the operative cure

TREATMENT

The only satisfactory treatment for chronic constrictive pericarditis is surgery Digitalis is of no avail and may possibly do harm if it reduces the pulse rate below the level which is optimal for the most favorable circulation in a given case Diuretics either by mouth or intravenously are only temporarily helpful They may however aid in tiding a patient along for months or years if his condition is for any reason inoperable or if the patient refuses surgical treatment They are helpful also in pre paring the patient for operation The best diuretic for the purpose is either salyrgan or mercupurin 2 cc (1/6 dram) intravenously at inter vals of one to four weeks as needed with or without the aid of ammonium chloride (1 Gm —15 grains three times a day) or similar salt by mouth Paracentesis is invaluable in the cases not operated upon and in preparing the patients for operation Usually such paracentesis is confined to the abdomen but now and then the chest cavities need to be emptied also In the old days these patients were subjected to abdom inal paracentesis once every week or two or three for years on end a very disagreeable but necessary act

Finally before proceeding to the radical cure of chronic constrictive pericarditis two palliative measures of value may be mentioned *i e* limitation of physical activity and restriction of fluid food and salt intake

Exercise by increasing the demand of the body for an active circula tion almost invariably aggravates the condition and the degree of con gestion A patient with chronic constrictive pericarditis who attempts to carry on his normal life is almost sure to grow worse despite other medical measures He adds weight in the form of fluid in the abdomen and extremities When he rests completely in bed he usually improves rapidly for a while and has a spontaneous diuresis At half or mild activity he is able to carry on sometimes fairly well if not badly affected Some patients however are so seriously damaged that they must remain complete invalids and even then may go on to early death The indi vidual patient quickly finds his optimal level of activity

From the beginning it was appreciated that the more fluid ingested by a patient with chronic constrictive pericarditis the more pronounced were the signs and symptoms of congestion A sharp reduction in intake of fluid in 24 hours may lead itself to a diuresis When the intake of fluid in 24 hours is kept below 1 liter (1 quart) and sometimes as low as 500 cc (1 pint) the patient if not too severely diseased may get along fairly well with little or no need of tapping but the continuance of markedly limited fluid intake may prove very uncomfortable and the patient may therefrom lead an unhappy existence It is well to keep the total food intake at a rather low level (but with adequate protein) to prevent overtaxing the digestive tract which is already somewhat congested and functionally inefficient Of particular importance is a reasonable restriction of total sodium chloride intake about 5 Gm (1¼ drams) instead of the usual 10 to 15 Gm. (2½ to 3¾ drams) per day

with resection by special blade of the left part of the sternum It is of considerable importance to identify and retract the pleurae, which are also often thickened and out of their normal positions When anesthesia is carried out as has been the practice by Churchill at the Massachusetts General Hospital under tracheal insufflation of ether with the patient *in the sitting position in a* dental chair, there is no great harm in allowing air to enter the pleural cavities if by chance they should be opened

The pericardium is identified and opened near the apex of the heart If it is completely adherent it has to be incised and an attempt made to peel it off from the heart itself The process of decortication of the heart sufficient at least to give some relief usually takes about one hour Since the involvement is usually anterior the decortication begins near the apex and *extends over the part of the left ventricle near the ventricular sulcus* over the right ventricle beyond the auriculoventricular groove over the right auricle and if necessary down over the inferior vena cava and up over the superior vena cava although usually there is not much involvement of the veins (In one case observed a calcified band was excised from its position overlying the inferior vena cava)

The pericardium should not be cut off in large masses There should always be *a small bit of pericardium left attached to the heart in* case of rupture of the wall of either right ventricle or right auricle if the wall is torn, the pericardial tab may be sewed over the rupture This was done in two of our successful cases

How much of the posterior heart chambers *i e*, the left ventricle and left auricle should be decorticated is for the future to decide Some of the writer s cases have given evidence of posterior constriction but decortica*tion of the posterior heart chambers was not attempted One* case has been reported in Germany in whom there was a successful decortication first of the anterior surface of the heart and at a later operation of the posterior surface of the heart

During the operation it is encouraging to find the heart increasing visibly in size and degree of pulsation while it is being decorticated The pulse pressure may definitely increase during the operation In a case done by Churchill the pulse pressure increased at once from 20 to 30 with obvious improvement in the heart s action Good judgment must be used in deciding when to stop the operation It is to be recognized that *it is possible to carry out a second operation if the first has not been com*

plete enough. This was done in two of the writer's cases, and the approach the second time proved to be very easy, there being no ribs to remove and no pericardium to penetrate first in approaching the field of operation. The reformed adhesions were nonconstricting.

The patient is returned to the ward and kept in an oxygen tent for the first day or two, or as long as may be needed. Great care postoperatively to empty the pleural cavities of fluid, if they fill rapidly, and expert nursing are essential. Some patients recover very quickly with spontaneous diuresis directly after the operation, while others take months for their improvement, the cure going on progressively for close to a year. Still others show little or no improvement, and a few cases may die as a result of the operation.

In a series of 28 cases at the Massachusetts General Hospital, 20 have been operated on by one surgeon (E. D. Churchill). Of these 20 cases, 11 through December, 1939, were cured so far as chronic constrictive pericarditis is concerned, one was about one half relieved; one was about one quarter relieved; and seven died, two on the operating table because of the severity of the illness, one the day following operation, one six days after the operation, and three others months later from the disease itself or from complications. Unexpected accidents may sometimes occur in cases that otherwise seem favorable Such happened during operation in two of our very young patients; in one of these the auricle was torn during the pericardial resection, but the tear was quickly repaired by the use of a bit of the pericardial flap still attached, and no harm was done; for she is well today over six years later; in the other case a girl of 13 at the end of the operation the right heart, which was very thin, dilated to a high degree, and death came in a few minutes, apparently as a result of the failure of the right side of the heart.

In the cases that have been cured clinically, there has been a disappearance of all evidences of congestion, except that there may still be a slight elevation of the venous pressure above the normal, and persistence of slight enlargement of the liver. The electrocardiogram may remain abnormal, but frequently it improves in appearance.

ILLUSTRATIVE CASES

Chronic constrictive pericarditis varies so greatly in its manifestations and response to treatment that it will be helpful to present certain illus-

trative cases The first will show the excellent curative result in a severely affected young child. The second will demonstrate a successful result in a young man, more frequently encountered than other types The third will represent a difficult but nevertheless successful case in a middle aged man The fourth will show a failure

CASE A *Successful result of operation in a severely crippled child*

B K now (July 1939) aged 17 years This girl was reported in full up to 1935 in the Lancet London September 7 and 14 1935 pages 539 and 597 as follows

B K a girl aged ten entered the hospital on October 13 1931 with a history of having lived a semi invalid life since the age of 3½ due to a markedly enlarged abdomen resulting from the presence of much ascitic fluid When she was 20 months old she suffered from what was apparently an attack of acute pericarditis and her abdomen became enlarged At the age of 2½ years a laparotomy was performed and a gangrenous appendix was removed No tubercles were seen on the peritoneum at the time of operation A drain was inserted and the patient made a good recovery The fluid returned in about three weeks but following an abdominal tap one month later there was no recurrence of fluid for three years At the age of 5½ the abdominal fluid returned and six months later a Talma operation (omentopexy) was done Abdominal fluid injected into a guinea pig gave negative results There was no improvement following this operation and at the age of nine the patient entered a second hospital for further study Her abdomen was tapped at that time but not again after that until her entrance into the Massachusetts General Hospital in the fall of 1931 when 6240 cc of straw colored fluid with a specific gravity of 1 013 were removed

Her mother had died of tuberculosis during the patient s infancy Her father is living and well

Physical examination showed a thin somewhat pale young girl with heart apparently normal in size and sounds and without murmurs and with prominent jugular veins and a large protuberant nontender abdomen filled with fluid (Fig 2A) X ray examination showed heart and great vessels somewhat displaced to the right and anchored to the diaphragm no pulsation was evident at the right border of the heart and great vessel shadow the right pleura was thickened

The electrocardiogram showed normal rhythm rate 100 with inverted T waves in Lead II

Advice was given at that time that the chest be explored surgically and the adhesions constricting the right auricle right ventricle and the great veins be freed

"After an interval of two years this girl returned to the hospital in an unchanged condition with persistence of the enlargement of the abdomen The serum protein measured 4 3 per cent X ray and electrocardiographic findings were as before

"Pericardial resection was carried out on November 16, 1933, and a moderately thickened pericardium containing calcareous plaques was removed from over the right ventricle and right auricle by Dr Churchill The pericardial tissue that was removed showed fibrosis and calcification on examination There was a stormy time for two days after the operation, and during the first two weeks there was no apparent improvement About four weeks after the operation spontaneous diuresis began, and in the course of a few months the ascites completely disappeared (Fig 2B) She has been in excellent health since, and looked well when she was last examined by us on May 16, 1935

The electrocardiogram on May 16, 1935, showed normal rhythm at a heart rate of 80, with slightly upright T waves in Lead I, flat T waves in Lead II, and very slightly inverted T waves in Lead III, this record differed from that taken before the operation in that the T waves were more normal and the voltage of the QRS waves was greater"

I saw her again a few days ago and will add after this previous account of her a note as to her present condition

Recent Follow up—July, 1939 Good health and rapid growth have characterized the last four years except that during the past few months there has been some evidence of easy fatigability Physical examination now shows a tall, slender, somewhat delicate appearing girl (Fig 2C) with normal heart sounds and size The electrocardiogram shows normal rhythm, rate 95, slight right axis deviation low T waves in Lead I, inverted T waves in Lead II, and inverted T waves in Lead III

Blood examination shows a normal smear, minimal achromia, and no abnormal cells

The rapid growth and slight anemia in this girl are responsible for her present somewhat frail state of health, but fundamentally she seems all right and there is no evidence whatsoever of any recurrence of the trouble associated with her constrictive pericarditis for which the operation was so successfully carried out six years ago See the illustration herewith showing her in 1931, 1933, and 1939 (Fig 2)

CASE B *Successful result from operation in a young man with moderate involvement but not wholly incapacitated A common type*

O W P, chemist, 31 years old in 1939

Chief complaint on first examination July 23, 1936, was of dyspnea and edema of 15 months duration

History He had always been well in childhood and early youth, and periodic examinations in the Officers Reserve Corps prior to the present

of the liver and edema of the legs associated with a heart normal in size and without evidence of valvular disease The course of the illness was characteristic It was natural that one could expect little benefit from medicine Digitalis was entirely ineffective Therefore pericardial resection was at once advised

The operation for pericardial resection was carried out by Dr Edward Churchill on October 8 1936 The pericardium and epicardium were but slightly thickened but both were markedly constricting the action of the heart There was a moderate amount of fibrin between the layers and in one pocket there were 5 or 6 cc. of clear yellow fluid There was no calcification of the pericardium The pericardium and epicardium were both successfully removed so that the systolic-diastolic excursions of the beat were markedly increased at the end of the operation

Postoperative Course There was an astonishingly rapid convalescence from this operation and he was discharged from the hospital 15 days after operation

On November 16 1936 the following note was made on his record Had a satisfactory trip home from hospital to Milo Maine by train in company of nurse Marked spontaneous diuresis occurred with a common cold about one week after going home Since then there has been no fever His edema entirely disappeared following this diuresis except that a minimal amount may be present about the ankles with recent increase in activity Dyspnea is absent except to a slight degree on such exertion as climbing two flights of stairs Lowest weight 122 pounds occurred after diuresis greatest 132 now Has been eating very well taking a high protein diet He has noted no cyanosis or jugular distention and none of the dizziness and flushing on bending over which was a preoperative complaint Pulse rate 78 to 80 On physical examination he looked well His color was good The circumference of his abdomen at the epigastrium was 30½ inches at the umbilicus 30¼ inches (standing)

He visited me again recently (August 1939) in excellent health with no symptoms working hard and with normal physical examination except for the old surgical scar in his precordium His venous pressure was normal and his liver was no longer enlarged

CASE C *Successful result from two risky operations in a seriously crippled middle aged man a difficult case*

G P male 47 years old in 1939 Banker

Chief complaint Swelling of abdomen and legs gradually coming on over an interval of several years prior to examination August 1935

History In 1932 this patient noticed gradually increasing prominence of his upper abdomen requiring him to alter his clothes This he ascribed to the familial tendency to become somewhat portly in early middle age Prior to this observation he had always been well The only illness to

which it may be possible to ascribe this disease was a mild influenza three years before One other condition which had bothered him for many years consisted of extensive varicosities of the veins of both legs complicated on two occasions by phlebitis once in his right leg and later *in his left Early in 1934 his wife noticed increasing cyanosis of his lips* and a little dyspnea on effort Shortly after that in the spring of 1934 he consulted his family physician and an x ray study at that time disclosed the presence of pericardial calcification The diagnosis of chronic con strictive pericarditis was made Early in 1935 auricular fibrillation devel oped with an increase in his symptoms of dyspnea cyanosis and edema The ventricular rate however was readily controlled by digitalis and he improved again but still was considerably disabled by the symptoms above mentioned

Physical examination August 6 1935 showed a middle aged man well developed and nourished except for evidence of slight loss of weight *in the upper part of the body particularly in the shoulders and arms* The breathing was normal and the color was good The pupils were equal and reacted normally to light There was no arcus senilis exoph thalmos or thyroid gland enlargement The teeth showed much dentis try The tonsils were small The tongue was clean The cervical glands were normal There was a moderate increase in size of the cervical veins with slight pulsation visible There was no abnormal arterial pulse in the neck The heart was normal in size The apex impulse appeared to be less forceful than normal The heart sounds were diminished except for the pulmonary second sound which was reduplicated There was absolute arrhythmia but there were no murmurs thrills or friction rub and there was no Broadbent s sign There was no precordial tenderness The radial pulses were small and equal and slightly paradoxical in char acter The radial artery walls were soft The lungs showed slight dull ness and diminished breath sounds with a few fine atelectatic rales at the left base There was no evidence of pleural fluid The abdomen was moderately distended in its upper portion The liver presented a firm nontender nonpulsating edge 8 cm below the ensiform cartilage and 2 cm below the right costal margin in the nipple line The spleen was not palpable There was apparently slight ascites There was no edema over the back but there was moderate edema of the lower legs more on the right There were varicose veins of both legs more on the right The knee jerks were equal and active The pulse rate was 70 The blood pressure was 125 systolic 85 diastolic in both arms

The urine was completely normal The blood counts and smear were completely normal

The serum protein was 6 3 mg per cent. The total plasma protein was 7 12 globulin 2 23 and albumin 4 89 The blood nonprotein nitrogen was 30 mg per 100 cc.

Liver function test showed a retention of 20 per cent of the dye in the serum one-half hour after injection

Electrocardiogram August 6 1935 showed auricular fibrillation rate 90 with inverted T waves in all three classical leads

X ray examination August 8 1935 showed extensive pericardial changes with calcification (Fig 4) pleurisy at both bases with thickening of the pleura old fracture of the seventh rib and changes in the lower lobe of the right lung consistent with partial collapse

A *diagnosis* was made of *chronic constrictive pericarditis with calcification and chronic pleuritis* Pericardial resection was advised.

Operation was carried out on October 18 1935 The operative notes are as follows

Ribs III IV and V resected close to costochondral juncture and costal cartilages removed to sternum Internal mammary vessels ligated at upper end of their exposure The intercostal bundles and left pleural reflection were stripped back from surface of pericardium until left phrenic nerve was identified Right pleural reflection not definitely visualized but extrapericardial tissues pushed back under sternum allowing resection of left border with the sternum knife The pericardium was dull and opaque It was opened over the right ventricle and here was found a considerable area of thin pericardium with relatively light adhesions Crossing obliquely across the field in the sulcus between right and left ventricles was a thickened cord like band containing a core of calcium 1 5 mm in diameter intimately adherent to the pericardium Another incision was made over the left ventricle so this was approached from both sides and removed The outer end of this band extended to a thick shell of calcium over the left ventricle and left auricle This was removed to line of the phrenic nerve Medially and inferiorly this band thickened into dense plaques running into diaphragmatic pericardium This was removed as far as accessible Considerable venous oozing from the heart occurred in this region when the calcified plaques were removed The auricle was covered with a heavy shell of calcium and it was thought wise not to attempt to remove this shell What was accomplished was a wide ventricular decortication back to the phrenic nerve and beneath the sternum Considerable gain in expansion and mobility of the heart was obtained

Because of an unusual amount of venous oozing a small rubber wick was placed in the lower angle of the wound which was otherwise closed with silk.

He was discharged on December 11 1935 somewhat improved.

Later Notes September 24 1937 He has had an excellent six months past gaining in strength and morale but still limited physically by dyspnea and still requiring occasional belly taps (February 19 four quarts April 5, 3½ quarts May 11, four quarts June 2, four quarts July 28, two quarts) No tap in past eight weeks The hot weather was doubtless favorable last month in keeping his fluid balance more satisfactory Weight always 173 to 174 pounds with pajamas after tapping Goes to town at ten o clock daily and returns at five (lunch 12 30) Not overtired Acute cold last March Was in Nova Scotia for three weeks in August

Physical examination Looks well Pulse irregular at 88 Blood pressure 110 systolic, 75 diastolic in both arms Trace of edema over both shins and feet (wears elastic stockings) Moderate distention and pulsation of neck veins—estimated venous pressure 18 (plus) cm Heart Apex impulse in fifth space 9 (plus) cm to left of midsternal line (midclavicular line 9 cm out), vigorous pulsation Heart sounds good no murmurs Lungs slight dullness and diminished breath sounds at both bases (thick pleura) Liver as before—hard nontender—edge 7 cm below costal margin

Electrocardiogram Auricular fibrillation ventricular rate 85 to 90 inverted T waves in Leads I II and III (only slight of T_1) Low T_4

Fluoroscopy Slightly enlarged centrally placed heart with calcification at apex, left border, and lower border, pulse small on both sides both eaves of diaphragm restricted right heart border hazy but not calcified lung hilus shadows not especially increased nor is pulmonary artery transverse diameter of heart 14 2 cm internal diameter of thorax 27 6 cm

Comment General condition excellent Still enough constrictive pericarditis to semicripple him and he should have another attempt made to clear away the offending pericardium He is a good risk for this much better than the first time and the approach will be much easier

The second operation for pericardial resection was carried out October 21, 1937, as follows Old scar excised At lower end of incision considerable scar tissue bound the heart to the sixth costal cartilage This was resected and in itself appeared to give considerably more freedom to the heart. Under this region there was fatty tissue in relation to the apex In following a false cleavage plane the right ventricle was opened but was closed by sutures. Then dissection was carried further to the right, picking up the edge of the calcified shell This was freed from the heart over a considerable area by extremely cautious and painstaking dissection as an opening into the heart chamber under the thick calcified shell would have been catastrophic. It was difficult to recognize the boundaries of the dissection as landmarks were obliterated Probably I got a little way onto the auricle, but I am not sure There is con

siderable calcium left in the region of the auricle and diaphragmatic surface Perhaps it could be best exposed by a subxiphoid incision if further operation is ever contemplated Signed by Dr E D Churchill

He was finally discharged January 29 1938 considerably improved after a stormy convalescence delayed by recurrent pulmonary embolism

In July 1939 he is in good condition He has had an excellent year quietly active in his work with no symptoms and requiring no further abdominal taps for well over a year now By orthodiagraphy there is evidence of calcium along the left edge and diaphragmatic surface of his heart

Structurally there remains much that is wrong but functionally he is to be considered a cure

Later Note April 1940 He is in excellent health over two years after his second operation

CASE D *Death after operation in a severely ill patient* (formerly published as Case 13 in the Lancet article September 1935)

J A H male 59 a shoe worker began to notice shortness of breath on effort in January 1932 In July 1932 swelling of the ankles began In September his edema had reached the thighs and he was hospitalized for five weeks At Christmas time he had the grippe Pleural effusion developed and in February each pleural cavity was tapped with the removal of much straw colored fluid He showed some asthmatic wheezing after each tap Chest taps were continued from April 1933 at the rate of about one a week until his entrance to the Massachusetts General Hospital on September 23 1933 He lost strength steadily over this period of time but the edema of his legs subsided somewhat His past history was entirely unimportant He had tonsillectomy eight years before after tonsillitis Family history was unimportant

Physical examination on admission to the Massachusetts General Hospital on September 22 1933 showed a well developed and nourished man slightly dyspneic but in no great discomfort The cervical veins were engorged and pulsating with his head and neck at an angle of 45° The cardiac apex impulse was poorly felt Percussion dullness was slightly increased The heart rhythm was absolutely irregular and the rate was 60 The blood pressure was 104 mm systolic and 60 diastolic There were a moderately loud blowing systolic murmur and a loud third sound at the apex The pulmonary second sound was slightly accentuated and reduplicated There were no diastolic murmurs The pulses were small There was dullness to flatness below the angle of the right scapula and at the extreme left base with diminished breath sounds and slight pleural friction rub at the right base There was slight edema over the lower back and of both legs up into the thighs There was moderate ascites

The liver edge was palpable five fingers breadth below the costal margin it was not tender

Fluid which was obtained from abdominal and pleural cavities was evidently a transudate When inoculated into a guinea pig the abdominal fluid was negative for tuberculosis

The urine showed slight albuminuria The blood was normal except for slight secondary anemia The serum protein measured 5 3 per cent The Wassermann reaction was negative

X ray examination showed extensive calcification of the pericardium especially in a circular region from the pulmonary artery downward to the diaphragmatic surface of the heart and transversely to the midline Pulsation of the heart was not evident except at the apex where it was quite distinct There was considerable fluid in both pleural cavities

The electrocardiogram showed auricular fibrillation with a ventricular rate varying from 60 to 110 and markedly low voltage with inverted T waves in Leads I and II

After observation in the ward over a period of ten days this patient was transferred for operation and on September 30 1933 Dr Churchill performed pericardial resection The pericardium was found greatly thickened and calcified particularly over the right ventricle The line of cleavage was established over the left ventricle and the pericardium was freed around the apex at the left side of the heart With considerable difficulty the calcified pericardium was removed from the right ventricle and the diaphragmatic pericardium was resected down to the vena cava There was a stormy postoperative course with pulmonary edema Both pleural cavities were again tapped the right on October 3rd and the left on the 4th He died suddenly on October 5th

Postmortem examination showed chronic adhesive pericarditis with calcification especially posteriorly but without evidence of tuberculosis acute and chronic bronchitis and slight bronchopneumonia pulmonary edema slight right hydrothorax chronic fibrous bilateral pleuritis marked cirrhosis of the liver of the chronic portal type (not of the lesser degree associated ordinarily with cardiac cirrhosis) perisplenitis cholelithiasis ascites and peripheral edema

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CHAPTER XVIII

CARDIAC HYPERTROPHY AND DILATATION

(CARDIAC FAILURE)

By HUGO ROESLER M D

Introduction *Hypertrophy and dilatation of the heart are common* in primary diseases of the cardiovascular system Both conditions also occur in many systemic diseases, some of which are known and under stood moderately well while other conditions which are undoubtedly a factor have not yet been classified It should be realized at the outset that the presence of a heart of normal size and shape does not preclude *the possibility of cardiovascular disease or abnormality*

Gauges for estimating the size of the heart during life relate to the size of the muscle plus its blood content *i e*, to the heart s volume The normal heart size shows a certain range of variation and hypertrophy alone or with little dilatation may not be discoverable clinically or radio logically The term enlargement is less committal and often preferable to hypertrophy and dilatation because the determination of these com *ponents is mostly uncertain An exception of this generalization may* hold true for cases with glomerular nephritis where an hypertrophy of the left ventricle as evidenced by the character of the apical thrust may be diagnosed within a short time An hypertrophy of the right ventricle certainly can be diagnosed clinically only if there is present some degree of dilatation Perhaps the term enlargement should be reserved for *those cases where we are unable to find evidence for hypertrophy such as* noted for instance in patients with coronary artery sclerosis In sum marizing, we may say that pure hypertrophy without an associated appreciable degree of dilatation can be diagnosed only very rarely, but if there is a definite dilatation present, there is no difficulty in finding evidence for the presence or absence of hypertrophy

The lay individual is fearful of the diagnosis of enlargement as an indication of an incurable condition leading sooner or later to death The practitioner is likely to diagnose this condition as a disease, *per se* Of course it is not the enlargement which is injurious but the cause of the enlargement A full understanding of cardiac enlargement, of its functional and prognostic evaluation, and of proper treatment demands knowledge of the conditions which produce the change and of the rate at which they act.

Going a step further, it may be said that the general term enlargement is not sufficient it is necessary and possible to determine the particular enlargement of the separate chambers of the heart

PATHOLOGY, MECHANISM, DEVELOPMENT

From the viewpoint of pathology, *hypertrophy* connotes an increased weight of the heart and *dilatation* indicates an enlarged capacity of the cardiac chambers Dilatation and hypertrophy are in many instances sequelae to increased tension of the heart muscle fibers, associated with an increased energy expenditure Best understood is the influence of mechanical factors Common conditions such as hypertension defects of the heart valves, and rare conditions such as defects of the septa, arteriovenous fistula, a certain type of adhesive mediastinopericarditis Less well understood is the mechanism when the coronary arteries or the myocardium primarily is affected It is thought at the present time that an insufficient blood supply to the myocardium over a sufficiently long period of time may occasionally be responsible for hypertrophy and dilatation In this connection may be cited coronary artery disease, both of the atherosclerotic and syphilitic type, and the severe anemias Much investigation remains to be done as to the causative role played by rheumatic and other forms of myocarditis, hormonal influences (thyroid, pituitary gland), nutritional disturbances (B avitaminosis), and metabolic disturbances (storage diseases)

The term *tonogenous dilatation* refers to a compensatory dilatation of the healthy heart muscle because of an increased resistance to outflow of blood It begins in the outflow tract of a ventricle, which is below the aortic orifice in the left ventricle and in the pulmonary conus in the right ventricle, and progresses against the direction of the blood stream down to the apex Subsequently and slowly, the inflow tract is involved, again

in a direction opposite to that of the blood flow so that the dilatation finally reaches the respective A V rings Elongation of the heart prevails over widening (See the anatomic illustration in Chapter XXIX) *Myogenous dilatation* refers to dilatation closely associated with impaired contractility of the damaged myocardium It involves simultaneously all parts of the affected ventricle quite uniformly and the result is a predominance of widening over elongation

Predominance of dilatation indicates that the heart was beating inefficiently and has been unable to completely discharge its contents Dilatation is often associated with hypertrophy but also occasionally with thinning of the walls In the latter case a local dilatation is in the foreground (aneurysmal thinning out of the ventricular or atrial* wall)

It is almost needless to point out that more than one etiologic factor may be responsible for *cardiac enlargement* To cite only a few examples In four fifths of patients with coronary thrombosis in whom enlargement is found it is due to associated hypertension If enlargement in the course of thyrotoxic disease occurs it is chiefly due to the association with coronary artery disease auricular fibrillation and cardiac failure The combination of emphysema and hypertension is common

Enlargement may affect the chambers of the heart unequally In respect to the left ventricle the following factors may be mentioned Hypertension (of any etiology including acute and chronic glomerulonephritis and coarctation of the aorta) aortic regurgitation mitral regurgitation aortic stenosis (hypertrophy prevails) coronary artery sclerosis aneurysm of the wall The right ventricle is involved predominantly *in the presence of mitral stenosis in the late stages of congestive failure* from almost any cause occasionally in the presence of systemic hypertension without failure chronic disease of the pulmonary parenchyma such as emphysema obstructive disease in the lesser circulation (sclerosis endarteritis chronic embolization) tricuspid regurgitation interatrial septal defect pulmonic regurgitation or stenosis (hypertrophy prevails) B avitaminosis The left atrium is particularly enlarged in the presence of mitral valvular disease and this is especially the case *when the disease results from fibrosis of the wall following rheumatic* myocarditis but is also observed with failure of the left ventricle while

* Except in connection with fibrillation the term atrium (atrial) rather than auricular will be used

for the right atrium mention should be made of right ventricular failure, tricuspid regurgitation or stenosis, and the interatrial septal defect It should be stated that the degree of enlargement in the presence of valvular lesions does not always seem to be closely correlated with the apparent extra load

The principal direction of expansion of the different heart cavities is as follows Left ventricle dorsad* and to the left, but also the right and

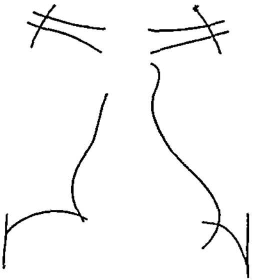


FIGURE 1 Male age 36 Had measles in childhood no other disease This healthy athlete had 14 years of skiing ice skating bicycling and high mountain climbing He felt fine was of a strong muscular build his height was 184 cm. and his weight was 86 kg (189 pounds) The apical thrust was hardly felt the heart sounds were clear and without basal accentuation The heart rate was 64 per minute the B P 130/80 The following were the orthodiagraphic measurements Width of chest 23 7 cm oblique diameter 15.2 cm broad diameter 10 4 cm

Comment The heart therefore is at the upper maximal limit of normal size and perhaps slightly exceeds it Such a finding should be looked upon as a physiological process of adaptation to tests of endurance which require an increased stroke volume over a long period (Roesler Am. J Roentgenol)

ventrad* right ventricle to the left and ventrad, but also dorsad, left atrium dorsad right atrium to the right and ventrad

The more generalized form of enlargement is noted with a number of conditions, some common and some rare, *viz*, combined valvular lesions advanced stages of congestive failure of varied etiology, myocardial lesions in the course of rheumatic fever, diphtheria, grippe and typhoid Fiedler's type of myocarditis myxedema, acromegaly, and severe and prolonged anemia In this connection it is proper to state

* The terms ventrad and dorsad will be used instead of anterior and posterior

that all myocardial lesions of toxic infectious endocrine or nutritive origin may lead, but not necessarily, to cardiac enlargement Among other causes may be mentioned arteriovenous fistula, marked bradycardia, glycogen storage disease rhabdomyomatosis hemochromatosis with infantilism transposition of the great arterial vessels common arterial trunk, origin of one or both coronary arteries from the pulmonary artery bilocular and trilocular heart

Prolonged and strenuous physical activity carried on as endurance tests (skiing, rowing cycling long distance swimming and running) may, but need not bring about a slight degree of enlargement which should be looked upon as a physiological process of adaptation (Fig 1)

Enlargement of a few special types is reversible and this will be mentioned under the treatment

Juvenile organisms acquire an increased mass more rapidly than older organisms and hence the greater tendency toward enlargement in youth than in adult life Hypertrophy requires at least three to six weeks for its development and this may take place in a case with rheumatic infection and developing valvular lesion in spite of complete bed rest

The rate and degree of development of enlargement depends first upon the severity of the disease The more marked for instance the toxic damage the greater will be the cardiac enlargement A second factor which contributes to cardiac enlargement is physical overexertion while the process is still active Enlargement, as a rule, is not steadily progressive It is likely to remain fixed in its degree and stay so for months or years

Acute dilatation of the heart is undoubtedly a rare condition Severe toxic damage such as noted in the presence of diphtheritic infection is perhaps the best instance The right heart may dilate subsequent to pulmonary embolism Contrary to common belief, general enlargement does not follow an attack of coronary thrombosis This remark does not apply to the development of an aneurysm which takes the form either of a localized bulge or, if located in the apical portion simply causes an *elongation of the heart This may occur within a* week following the infarct

A healthy heart may dilate suddenly This is clearly noted in fluoroscopy during the pause following a premature ventricular beat likewise, when the breath is held the glottis closed and a strong effort is

made to inspire. *Strenuous exertion never causes dilatation of a healthy heart.* No reliable data is available as to the response of the severely diseased heart. Paroxysmal rapid heart action may be followed by dilatation, but only in connection with the development of congestive failure. Care should be taken not to confuse acute dilatation of the heart with collection of fluid in the pericardial cavity. Another diagnostic error occurs in thinking of an acute cardiac dilatation when actually vasomotor collapse is present.

DIAGNOSIS

Enlargement of the heart in the living is studied in both its static and dynamic features by inspection and palpation of the chest wall, and by roentgen rays. Percussion is to be carried out, but should be controlled by radiological methods whenever possible. The electrocardiographic study is of limited value in the diagnosis of enlargement *per se*, but is very useful for coexisting features.

Inspection and Palpation: The outermost limit of the apical thrust is the best clinical guide in evaluating the size of the left ventricle. In adults it is visible in not more than one-fifth of all cases, and it is rather uncommon to palpate it in the recumbent position of the middle-aged or elderly person; if well-defined in this position, and at this age, the presence of hypertrophy should be suspected Position and quality of the apical thrust may lead the examiner to erroneously assume the presence of some cardiac enlargement where there is none. Such an obtrusive apex beat slightly outside of the nipple line is noted particularly in children when there is some right-convex scoliosis of the spine: in boys during the rapid growth period of puberty; and in association with augmented heart action, as noted in the presence of thyrotoxicosis. The apical thrust is neither felt nor seen in the obese and emphysematous, and is poorly palpable and shows a systolic retraction in the presence of mitral stenosis where enlargement of the right ventricle pushes the poorly filled left ventricle away from the ventral chest wall. Tricuspid regurgitation, muscular or endocarditic in nature and associated with or without other valve lesions, has the same effect. Only in exceptional instances of excesssive enlargement of the right ventricle and of the right atrium, pushing the left ventricle to the left, such as is noted in instances of an interatrial septal defect, will a heaving apical thrust be observed as a part of a diffuse systolic bulge of the precordium. The apical thrust is feeble

or not palpable in the presence of dilatation without hypertrophy, with fluid in the pericardial or left pleural cavity, with edema of the chest wall, and is usually absent in *constrictive adhesive pericardial disease.* Hypertrophy of the left ventricle causes a characteristic heaving, resistant apical thrust. *Dilatation superimposed on hypertrophy favors the* development of a forceful apical thrust, because the left ventricle is then in closer contact with the chest wall It is often noted that a fully compensated aortic stenosis or hypertension, with marked hypertrophy, does not reveal the presence of an apical thrust until dilatation supervenes. A very broad apical thrust indicates a marked degree of dilatation (unless a narrow chest and thin chest wall are responsible for it). This in turn signifies the inability of the heart to completely discharge its content Such a finding is, therefore, an unfavorable sign. The heaving and resistant quality of the apical thrust may be lost when failure sets in as expressed, for instance, by the appearance of gallop rhythm.

A careful study of the chest wall movement in heart diseases gives valuable information as to the underlying dynamics. For didactic purposes a slightly schematic presentation is offered:

(*a*) *Systolic Propulsion* (Quicker and More Marked Than the Dias*tolic Depression Which Follows*): *A large systolic bulge of the chest* wall, which is most marked half way between the left midclavicular line and the left sternal border, *palpable and often visible, is found predominantly in* patients with advanced mitral stenosis. Here the right ventricle is enlarged, and during the systole the depth diameter of the right ventricle is increased, with the enlarged left atrium pressing the heart ventrad and thus furthering the development of the systolic bulge. Associated with this propulsion over the midportion of the chest is a flattening out of the lateral areas, for obviously in a tense elastic system if a deformity is set up in one area, it will affect the entire system.

A ventricular aneurysm, arising as a rule from the left ventricle (usually following an anterior cardiac infarct) often gives rise to a cardiac thrust which is sometimes large and forceful in character. It is most commonly located at the level of the fifth left rib and, depending upon its seat, pulsations are situated lateral or medial to the midclavicular line and may approach the left sternal border. Pulsations caused by a ventricular aneurysm should be differentiated from those caused by right ventricular hypertrophy and dilatation in association with left atrial enlarge

ment. The former is more circumscribed and further laterad; the latter is localized more mesiad and its extension is more lengthwise, *i. e.*, along the sternum. The diagnosis of cardiac aneurysm is made more difficult in the presence of hypertension or mitral and aortic valvular lesions, for these conditions *per se* are responsible for a forceful cardiac thrust. Location of the pulsations in the fourth intercostal space, within the left midclavicular line, is definitely in favor of the aneurysmal origin of the pulsations. Furthermore, supporting evidence is obtained from the history and electrocardiographic findings indicating a preceding infarction. Conclusive evidence is given by observing the development of such a pulsation subsequent to cardiac infarction.

A strong propulsion of the left chest wall to the left and ventrad is caused by forceful action of an enlarged left ventricle, while on the right side there is commonly associated a simultaneous flattening of the ribs. Occasionally, in the presence of aortic regurgitation or hypertension, there may be noticed a jerky systolic shift of the entire chest to the left.

A primary systolic propulsion on the right side of the chest wall with the maximum of pulsation, as a rule, found in the right midclavicular line between the fourth and sixth ribs is noted in the presence of a high grade mitral regurgitation associated with an aneurysmal enlargement of the left atrium The mechanism is one of impact of the blood regurgitating into the left atrium which, in turn, approaches the chest wall. A forceful systolic propulsion of the right caudal portion of the chest wall is noted in the presence of tricuspid regurgitation, where the back flow of blood suddenly enlarges the liver, and this, in turn, is transmitted to the chest wall In both foregoing conditions a jerky shift of the entire chest to the right may be noted.

(*b*) *Systolic Depression* (Quicker and More Marked Than the Diastolic Propulsion Which Follows): Such a depression is mainly noted when the cardiac volume shows a sudden and abnormally great diminution during systole, and when simultaneously an abnormally large amount of blood flows out of the thoracic cavity. This is exemplied by cases revealing a high degree of aortic regurgitation, although this is not a constant finding, because the systolic change in the shape of the heart acts as an opposing force; and in the presence of tricuspid regurgitation. The more rapidly this outflow of blood takes place from the thoracic cavity, the less will the inflow of air and venous blood be able to keep pace with

and counteract the considerable fall in the systolic intrathoracic pressure Likewise, the increase in the marginal excursions of the ventricle exerts an aspiratory effect on the chest wall The systolic depression is, of course, followed by a ventrally directed diastolic movement which is rather slow If a systolic depression exists it will disappear when cardiac failure with congestion sets in this is because of the diminution in the stroke volume

Depressions are also noted if there is interference with the function of the pulmonary cushion, for it is obvious that the chest wall must follow the centripetal* movement of the heart if the lung does not quickly take up this space left vacant by the heart and the chest wall A rapid expansion of the lung parenchyma may be interfered with by pleural adhesion by atelectasis which is not uncommon in the immediate vicinity of an enlarged heart or because of a powerful apical thrust Localized soft tissue depressions are thus observed mesiad to the apical thrust in left ventricular hypertrophy and dilatation and laterad in right ventricular hypertrophy and dilatation

(c) Diastolic Propulsion (Quicker and More Marked Than the Accompanying Systolic Depression Which Either Precedes or Follows) This is noted in instances of chronic pericardial disease In adhesive pericardial disease the following points are worthy of consideration First, the inhibition of the systolic change in shape of the heart due to internal adhesions interfering with the normal propulsive forces—particularly of the apical thrust hence the effect of the systolic diminution in volume makes its appearance Second the effect of the systolic diminution is particularly marked because the mechanism of this diminution is altered by the presence of adhesions The longitudinal shortening of the ventricular cone is interfered with and, therefore, a compensatory increase in the marginal movements of the heart results Actually such cases reveal during fluoroscopy a remarkably large amplitude An aspiratory force on the chest wall, therefore makes its appearance Third, the aspiratory effect on the anterior chest wall is enhanced by the common association of pleural obliteration, which inhibits the lung parenchyma from acting as a buffer Since the systolic change in the shape of the heart is interfered with the centrifugal† impulse due to the diastolic filling

* The term centripetal is used instead of inward

† The term centrifugal is used instead of outward

of the ventricles acts unrestrictedly on the chest wall The resulting diastolic propulsion is directed mainly to the left and ventrad and is quite forceful while the systolic depression is often less impressive But exceptions occur In the presence of an obliteration of the pericardial cavity with external fixations to the inner chest wall *providing the heart muscle* functions well ventricular systole deforms the left chest wall which is followed by an elastic rebound during diastole This forces the heart into a passive expansion and is associated with a reduplication of the second sound

The second cause of diastolic propulsion is tricuspid regurgitation here the right ventricle empties its blood not only into the lungs and liver but also the influx of venous blood is counteracted Hence the diminution in volume leads to a systolic depression but the subsequent filling of the right heart causes a ventral and diastolic propulsion which is quicker and more abrupt than the preceding depression

It should be emphasized that the diastolic propulsion is often not recognized and is erroneously ascribed to systolic action of the heart on the chest wall Such an error in timing should not occur and is easily avoided by placing one hand over the chest and palpating the radial pulse with two fingers of the other hand

Percussion It is a subjective crude method which in the hands of the average physician yields rather inaccurate results An attempt is made to determine roughly the portion of the chest wall that overlies the heart Since the right heart chambers are in close proximity to the ventral chest wall one will obtain more reliable results as far as the right heart is concerned as compared with the left heart chambers the bulk of the latter are dorsally located and hence poorly available to percussion The most common error is finding the left contour too far to the left and too far craniad * Results are particularly poor in emphysematous and stout individuals An attempt should be made to determine the position and shape of the left upper portion of the contour the so called waistline of the heart If this waistline is preserved one will find only the slightest degree of dullness in the third left intercostal space A marked degree of dullness indicates that the waistline has gone *i e* there is an enlargement of the conus arteriosus which is the outflow tract of the right ventricle *The width of the dullness may extend from 2 to 8 cm towards the left of*

* The term cran ad will be used for up ard above

the left sternal border in the third intercostal space An increased flatness on percussion over the lower third of the sternum, caudad to the right lung liver border, indicates an enlargement of the inflow tract of the right ventricle The latter finding is particularly noted in patients who have had failure in the past A marked degree of flatness on percussion all along the sternum, starting as high as the level of the second intercostal space, and associated with a marked extension of the cardiac dullness to

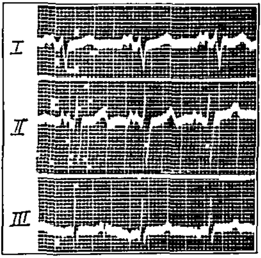


FIGURE 2 Female aged 39 Old rheumatic heart with mitral stenosis considerable cardiac enlargement and sinus rhythm which persisted up to death This took place two years later and was due to bronchopneumonia and pulmonary infarct (anatomic verification) Electrocardiogram reveals sinus rhythm there is present widening and notching of the P deflection in Leads I and II and a marked degree of right axis deviation is noted (initial deflection is down in Lead I and up in Lead III) (Cyclopedia of Medicine F A Davis Co)

the left particularly in the third intercostal space, speaks in favor of a pericardial effusion The left lower heart border should be percussed if the cardiac impulse is ill defined or not available Percussion of the right heart border helps to decide as to whether or not the heart is displaced

Electrocardiography Cardiac enlargement is compatible with a perfectly normal electrocardiographic tracing Muscle hypertrophy and more important, muscle impairment as a cause of or associated with enlargement, may find their graphic expression Most of such signs however are not specific for any one condition and should be evaluated together with the whole picture

A working knowledge of the appearance of the normal complexes and of the symbols used is a prerequisite for the following discussion

Changes will be discussed first for atrial and then for ventricular hypertrophy, often associated with dilatation.

(1) *Atrial Hypertrophy*, often associated with dilatation: In the presence of sinus rhythm one may find an abnormally enlarged P deflection, exceeding 2.5 mm. in height and 0.1 second in width, often associated with notching and splitting. This is noted in the presence of mitral stenosis, tricuspid lesions, and also occasionally in a failing hypertensive heart, and in all conditions causing an abnormally increased intra-atrial pressure. In mitral stenosis the changes are predominantly noted

FIGURE 3 Male, aged 45 This patient had suffered for several years from asthma, emphysema and bronchiectasis He showed right sided failure The B. P. was 115/60 The roentgenogram revealed a moderate degree of cardiac enlargement with marked prominence of the conus arteriosus. The ECG shows steep and tall P deflections in Leads II and III as noted with the cor pulmonale In addition we note right axis deviation for the initial deflection and, in association with it, those S to T segment changes in Leads II and III as observed in the presence of right ventricular strain. Digitalis medication was ineffectual, the diuresis was improved by organic mercury compounds Death took place three months later

in Leads I and II, widening and splitting being a common feature. In the presence of pulmonary emphysema, pulmonary artery sclerosis and pulmonic orifice stenosis, steep P deflections without widening and notching may be noted in Leads II and III. Their voltage may diminish during cardiac failure.

(2) *Ventricular Hypertrophy*, often associated with dilatation: (*a*) Axis deviation The findings in the presence of right axis deviation are a downward stroke of the initial deflection in Leads I or I and II, and an upward stroke in Lead III. The findings in left axis deviation are an upward stroke in Lead I, and a downward stroke in Lead III or in Leads II and III. In evaluating axis deviation, it should be borne in mind that the initial deflection should not be widened, as it is found, for instance, in the presence of bundle branch block. Right axis deviation, if well marked and showing a deep S in Lead I, practically always indicates prevailing hypertrophy or enlargement of the right ventricle. It is present in mitral

stenosis advanced and extensive disease of the pulmonary circulation or of the lung parenchyma with pulmonic orifice stenosis (congenital malformation) and occasionally subsequent to strain on the left ventricle (hypertension). A lesser degree of right axis deviation is noted with the hyposthenic habitus. Mention should be made of the right bundle branch block where of course the width of the initial deflection is increased. *Left axis deviation occurs more often and causes more difficulties in evaluation.* It is present with prevailing hypertrophy or enlargement of the left ventricle (hypertension present or past, aortic valvular lesions, etc.) and with a normal sized heart with the hypersthenic habitus, high *position of the diaphragm and obesity and in tricuspid atresia which is* a rare congenital malformation. Mention should be made of the common left bundle branch block in which a widening of the initial deflection is present. *In differentiating left axis deviation due to hypertrophy or* enlargement of the left ventricle from left axis deviation occurring in the hypersthenic habitus with high position of the diaphragm and obesity one will be helped by the following criteria. In the latter group one finds a normal appearance in Leads I and II while in Lead III not only the initial deflection but also T and often also P are directed downward. In the former group S is deep in Lead III and often also in Lead II while T in Lead III is positive. Another sign is of importance and that is the negativity of T in Lead I associated with a depression of the S T segment. Parenthetically it should be noted that such a finding is not necessarily an evidence of advanced myocardial disease. Axis deviation due to hypertrophy (and this holds true likewise for bundle branch block and for premature ventricular beats) shows a tendency for the T deflection to reveal a direction opposite to that of the initial deflection as observed in Leads I and III. That means that in the presence of left axis deviation T in Lead I and sometimes also in Lead II, is likely to be negative while right axis deviation is often associated with a negativity of T in Lead III and often also in Lead II. Furthermore the voltage of the initial deflection is usually large similar to the findings noted in the ECG pattern *observed in premature ventricular beats and unilateral bundle* branch block. If there is noted in such hypertrophy tracings an opposite direction of the initial and T deflections respectively the S T interval reveals a shift similar to the T deflection, *i. e.*, where the T deflection is

positive, the S-T segment is elevated, and where this segment is depressed there is present a negative T.

Enlargement of both ventricles may neutralize each other, and no axis deviation will then be noted. Furthermore, it may be stated that, generally speaking, a negative T deflection in the absence of axis deviation

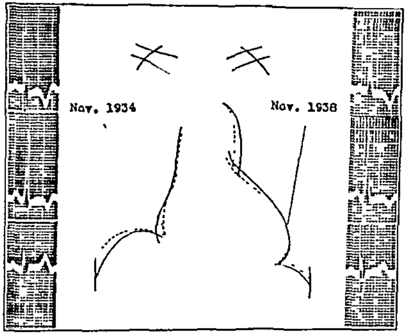


FIGURE 1 Female aged 50 and 54 respectively When first seen this patient had left ventricular hypertrophy, the B P was 160/105 There was no failure Fundi Retinal arteriolosclerosis grade 1 hypertensive type ECG Normal sinus rhythm marked degree of left axis deviation R to T segment in Leads I and II depressed and T negative in these leads. Orthodiagram showed evidence for left ventricular enlargement—L. 14.2, B 9.7 cm Three and one half years later this patient was observed during pneumonia, both axis deviation and negativity of T in I and II disappeared for a while, presumably *in connection with right ventricular strain Later on there was a transient period of* headache and dizziness, associated with a rise in the B P Four years following the original study patient revealed no changes in the clinical picture, B P was 200/105 Fundus picture and ECG were essentially the same The heart size had very slightly increased—L. 11.0 B 10.6 cm There was no appreciable effort limitation

Comment This patient showed the benign course of hypertension. The type of ECG depicted above indicates *left ventricular hypertrophy* and presumably strain It does not necessarily indicate advanced myocardial disease and is compatible with fair function

has a greater significance than in the presence of axis deviation. If T deflections become flat or negative, this does not necessarily indicate progressive enlargement of the heart, but signifies the presence of certain metabolic processes which disturb the electrical processes in the heart, although such abnormal states may well lead to dilatation. In the pres-

ence of cardiac enlargement there may be noted occasionally the presence of bundle branch block a lowering of the amplitude to less than 5 mm in either direction from the base line in all limb leads and changes in the T deflections These findings may be the sequelae of cardiac infarction or diffuse myocardial disease

It may be well to point out in this connection that flat or negative T deflections are noted in a number of other conditions such as myocarditis (rheumatism grippe diphtheria typhoid) B avitaminosis hypothyroidism alcalosis and acute or chronic cardiac compression due to pericardial disease Extracardiac neurogenic influences play a role and need further study Gallbladder disease has been held responsible Posture occasionally plays a role and a flat or negative T deflection particularly in Leads II and III may increase in voltage or even turn positive when the tracing is taken with the patient in the recumbent instead of in the sitting position

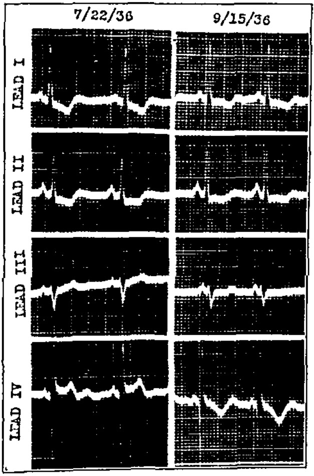
The influence of digitalis on the ECG (see Chapter XXXVI) should be mentioned here since this drug is so commonly used in connection with cardiac enlargement Its effect on the S T segment consists in a depression in the limb and chest leads usually most marked in Lead II and in a flattening out or inversion of the T deflections Where there is left axis *deviation however the aforementioned segment tends to be elevated in* Lead III No very close relation exists between the degree of these changes and the amount of the drug given *It may easily take two to three weeks and in occasional cases up to six weeks following discontinuation of the drug for such changes to disappear completely* If an ECG study is planned it is important therefore to withhold digitalis medication provided the condition of the patient will permit it

Cardiac enlargement may have to be differentiated from pericarditis In the latter condition particularly of septic etiology there may be an upward shift of the S T segment in all limb leads (see Dr Wilson s chapter)

Radiology *Fluoroscopy* is the method of choice A good dark adaptation of the retina is a prerequisite The oblique views must be studied in addition to the anterior view The screen image as obtained by fluoroscopy represents of course a considerable magnification of the object size This is overcome by taking an orthodiagraphic tracing The film image is obtained by a teleoroentgenogram at a distance of six feet

shows a magnification of nearly ten per cent. The absolute heart size is best determined by a computation formula:

Using the metric system, a product is formed from the oblique and broad diameter (anterior view) and oblique depth diameter (lateral view) and this is multiplied by 0.45. The value thus obtained expresses approximately the heart volume in cubic centimeters. The medium



value for healthy males is 569.2 and for the healthy female 422.6, with a standard deviation of 85.4 and 64.1, respectively. A simple and practical procedure is to rotate the sheet on which the orthodiagraphic silhouette is drawn by approximately 180° so that the base of the heart is pointing down, and place the patient's clenched right fist over the silhouette. These outlines will nearly coincide under normal conditions. It should be realized that the correlation coefficient between the size of the

FIGURE 6. Orthodiagrams of a normal heart as drawn in the anterior and left lateral views (reduced to one fourth actual size). The three main diameters are indicated by solid lines. Anterior view: The oblique diameter —L— connects the cardiovascular junction at the right with the farthermost point at the left lower pole. The broad diameter —B— represents the sum of the lengths of two perpendiculars dropped to the line of the oblique diameter. Lateral view: The depth diameter —Td br—is the sum of lengths of two perpendiculars dropped to a line which connects the region of the bifurcation of the trachea with the sternodiaphragmatic angle. As average figures for a male L, 13.6 cm; B, 10 cm; Td br—9.3 cm have been chosen. The volumetric cardiac value is *obtained by forming a product of these three figures times a constant 0.45* (formula of Benedetti and Bollini). The value thus obtained approaches the actual volume of the heart (as expressed in cubic centimeters). In this instance it is 569. This formula has been checked by actual volumetric reconstruction and submersion of the model in water. *The error for normal hearts was shown to between —8 per cent and +8 per cent and for* diseased hearts between —10 per cent and +15 per cent. (Cyclopedia of Medicine, F. A. Davis Co.).

silhouette and external measurements (weight, transverse diameter of the chest, etc.) is too low to have great statistical significance.

In the anterior view an enlargement to the left and caudad,* associated with a well preserved or lowered waistline of the left middle contour indicates left ventricular enlargement. *Care should be taken not to* include in delineation and measurement the triangular shadow which is caused by the extrapericardial, subpleural fat pad. The waistline will, however, be straightened out if a secondary right ventricular enlarge-

* The term caudad is used for downward below.

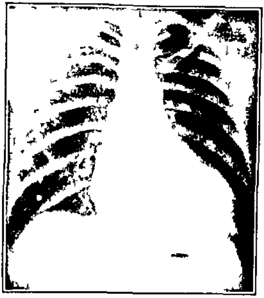
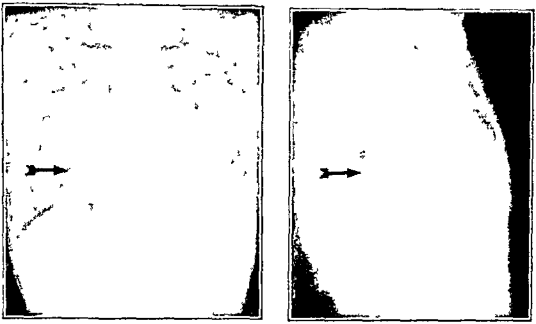


FIGURE 7 Male aged 25 Old rheumatic heart with aortic stenosis and regurgitation questionable mitral regurgitation marked degree of cardiac enlargement to left and sinus rhythm Moderate degree of functional impairment Roentgenogram reveals a fairly well marked aortic configuration with prominence of left ventricular area Lung fields are of normal appearance Calcification of aortic valves could be demonstrated by means of special technic (Cyclopedia of Medicine F A Davis Co)



A *B*

FIGURE 9. *A* and *B*. Male aged 19. Old rheumatic heart. Mitral valvular lesion, marked degree of cardiac enlargement, auricular fibrillation, good compensation. In the course of upper respiratory infections partial atelectasis of the left lower lobe developed on two occasions simulating pneumonic consolidation. Roentgenograms: *A*, Anterior view. Cardiac enlargement and general mitral configuration is noted. The enlarged aneurysmal left atrium bulges into the right lung field (arrow). *B*, Right lateral view. Note displacement of esophagus (arrow).

C

FIGURE 9. *C*, Left anterior oblique view of case shown in Fig. 8. Note displacement and narrowing of left bronchus (arrow). (Cyclopedia of Medicine, F. A. Davis Co.)

place over shorter periods of time, and it is important to obtain exact information as to the rate of progression. An increase, especially if rapid, gives a poor prognostic outlook. This holds particularly true in myocarditis or diphtheria.

CIRCULATORY FAILURE

When cardiac enlargement is diagnosed, circulatory failure may not be present, but it will result eventually. Hence, a short discussion of this finding is justified. Those forms which are primarily of extracardiac origin will not, however, be discussed. Here belongs first the clinical picture of inflow stasis (engorgement of the systemic veins and, less common, of the pulmonary circuit), which results from inadequate work of the heart due to inadequate filling, as noted in instances of pericardial effusion, chronic constrictive pericardial disease, or with extremely high heart rate; and second, the primary peripheral failure, *i. e.*, shock.

The commonest types of cardiac insufficiency are associated with inadequate emptying of the heart. The whole heart may be affected or strain may have acted predominantly on the left or right side, resulting in syndromes, which are spoken of as left- or right-sided heart failure. Before enumerating some symptoms and signs of heart failure, it must be kept in mind that one of the most important measures for a lowered circulatory efficiency is the subjective perception of the patient. *Taking a careful history, with particular reference to effort limitation, is, therefore, of paramount importance.*

1. Dyspnea: History may elicit the fact that dyspnea occurs on physical exertion; hence it is also called exertional dyspnea. In far advanced cases dyspnea may be present at rest. The main pathogenic factor is impairment of the ventilation of the lungs due to pulmonary engorgement. This is best noted by the radiologic examination and is compatible with both absence of râles and of cyanosis. The commonest causative factors are mitral stenosis, hypertensive and arteriosclerotic heart disease, hence affections of the left heart (left-sided failure). Hydrothorax, enlargement of the liver, and ascites, which are sequelae to right-sided failure, may aggravate the degree of dyspnea. But it is also noted that the onset of right ventricular failure subsequent to preceding left-sided failure leads to an amelioration because of the relief from pulmonary engorgement.

ment sets in. An enlargement to the left and craniad* leading to a prominence of the contour should be attributed to right ventricular (conus) enlargement, pulmonary artery dilatation often being associated. Left atrial enlargement plays a rôle only very occasionally. An enlargement to the right should be attributed, as a rule, to the right atrium, and only exceptionally to the right ventricle. Occasionally an aneurysmal distention of the left atrium accounts for it. In the right anterior oblique view, a convex bulge in front should be attributed to the right ventricle, and in this view the conus enlargement is particularly well noted. Dorsally, the mediastinum may be encroached upon by the left atrium and visualization of the barium-filled esophagus gives valuable information. In the left anterior oblique view, the right ventricle is seen to expand ventrad, the left ventricle dorsad and caudad, the left atrium dorsad and craniad. In the latter case, the left bronchus is displaced and sometimes considerably narrowed.

An understanding of the underlying pathology is enhanced by studying the size and shape of the aorta and of the pulmonary artery and its branches. The degree of pulmonary congestion can be estimated and is amenable to diagnosis long before the appearance of râles. Displacement of the heart may clinically be mistaken for enlargement, and the radiological method reveals almost at one glance the presence and degree of causative factors such as pleural effusion, pneumothorax, fibrotic shrinking or collapse of the lung, abnormal position of the diaphragm, or chest deformity. Augmented heart action is another cause for overestimation of heart size by clinical means. Finally, radiology may assist in differentiating cardiac enlargement and pericardial effusion.

FUNCTIONAL EVALUATION AND PROGNOSIS

While the physiologist considers enlargement of the heart muscle as a means of adaptation, the clinician is inclined to correlate these findings with potential or actual myocardial insufficiency. In the presence of coronary artery disease, cardiac enlargement is a much less valuable guide than in valvular lesions. Anginal failure is compatible with a normal heart size. Patients with coronary artery disease who develop cardiac infarction often reveal no change in heart size on follow-up studies. If this is the course of the disease, it will be found that a fairly active life is

* The term craniad is used for upward above.

carried on much more commonly as compared with those who either had cardiac enlargement to begin with or develop cardiac enlargement subsequent to the attack

Congestive failure rarely occurs in the presence of normal sized hearts In this connection it should be remembered that in chronic constrictive pericardial disease the heart is prevented from increasing in size, while failure of the circulation develops sooner or later

Patients with cardiac enlargement show, as a rule, a diminished capacity for work The term enlargement in this connection refers mainly to the ventricular mass Considerable enlargement of the heart *is likely to be followed by more or less rapid onset of failure* Auricular fibrillation sets in more frequently, and the same holds true of the occurrence of thrombosis along the atrial wall or in the coronary arteries

The general remark holds true that the larger the heart the worse the exercise tolerance experience with individual cases, however shows exceptions This holds true particularly for the younger age group who have healed rheumatic valvular lesions It may also be stated that there is no strict proportionality between the degree of enlargement and the signs and symptoms of heart failure Heart size is not more than a fair prognostic criterion and the clinician never should omit obtaining a correct idea as to the general physical tolerance of a patient Furthermore, the etiology and special anatomical features of a disease process are important items in the prognostic evaluation and should always be taken into consideration It is known that sudden death often occurs in the presence of coronary ostium stenosis due to syphilis with or without associated aortic regurgitation, or in the presence of a high degree of aortic stenosis, and in both instances this occurs regardless of heart size *The correlation of cardiac enlargement and mortality quota seems to be closest for patients with rheumatic valvular lesions* In one such very careful study on 1164 cases it was found that the mortality quota for all valvular lesions together for three groups of heart sizes, as determined by orthodiagraphy, was as follows The ratio of actual to expected deaths *for approximately normal sized hearts was 420 per cent, for moderately enlarged hearts 589 per cent, and for greatly enlarged hearts 1092 per cent*

It has been formerly stated that cardiac enlargement may be stabilized over a period of years In other instances, however, progression takes

place over shorter periods of time, and it is important to obtain exact information as to the rate of progression. An increase, especially if rapid, gives a poor prognostic outlook. This holds particularly true in myocarditis or diphtheria.

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Cardiac asthma may or may not be associated with dyspnea of effort, occurs particularly in the combination of the recumbent position and sleep, and is a symptom of left ventricular failure. It may be indistinguishable from bronchial asthma; hence, the importance of a good history.

Cheyne-Stokes respiration is also closely connected with left ventricular failure due to hypertensive, coronary, and aortic disease, but increased intracranial pressure and the effect of morphine, especially in arteriosclerotic individuals, must be remembered. This type of breathing is often overlooked; it may not occur until the evening hours and is an important cause for sleeplessness. The treatment consists in the slow intravenous injections of 0.25 to 0.80 Gm. (4 to 12 grains) of *theophylline ethylenediamine*.

2. **Cardiac Pain:** This symptom shows many varieties, and mention *may be made here that it is particularly apt to accompany occlusive* coronary artery disease (arteriosclerosis, thrombosis, syphilis), aortic valvular disease, and paroxysmal attacks of rapid heart action. Cardiac pain bears no close relation to cardiac failure or cardiac enlargement Right-sided failure may be associated with a diminution or disappearance of anginal pain previously present. The same may be observed some time subsequent to cardiac infarction; in such cases the one diseased arterial branch had been the only source for the anginal pain.

3. **Heart Sounds:** A lowered intensity of the first apical sound is often and not always correctly interpreted as evidence for heart muscle dysfunction. Leaving aside the possible influence of obesity or emphysema, it must be remembered that a relatively longer, though still normal, atrioventricular conduction time (for instance 0.20 second) tends to be associated with a first sound of lesser intensity. A similar and more marked effect is caused by mitral insufficiency, and also by aortic stenosis on the second aortic sound. Cardiac infarction, recent or old, tends to lower the intensity of the heart sounds. Besides mitral disease, an accentuation of the second pulmonic sound is noted with left-sided failure, whatever the etiology may be. *Gallop rhythm* is characterized by the appearance of a third heart sound, diastolic in time and usually dull in character. It is best perceived by auscultation, inspection and *palpation as well.* Gallop rhythm is likely to disappear with a slowing of the heart rate, and it is not heard in the presence of auricular fibrillation,

although graphic registration seems to indicate it may exist with the latter condition Mitral lesions tend to obscure it Gallop rhythm indicates, as a rule, failure of the left ventricle only, unless it accompanies acute myocarditis or pulmonary embolism The presence of gallop rhythm entails as a rule a bad prognosis, but this does not necessarily hold true if it is observed in the presence of acute myocarditis where it indicates a toxic damage of the heart muscle which may be reversible

4 **Blood Pressure** The effects of heart failure have a variable influence Cardiac infarction is commonly followed by a fall while a rise sometimes to a very marked degree, may be noted during an attack of angina pectoris or pulmonary edema A moderate rise with each bout of failure is noted in occasional patients It should be noted parenthetically that high blood pressure does not contraindicate the use of digitalis

During the measurement of the blood pressure alternation may be observed as a succession of strong and weak beats The loud sounds come through corresponding to only half the heart beats This finding should not be confused with an extrasystolic bigeminus An alternating pulse is not uncommonly encountered in patients with arterial hypertension Its presence particularly when continuous in nature indicates a poor prognosis

5 **Cyanosis** It is closely correlated with an increase in the amount of reduced hemoglobin anemia therefore, tends to counteract the appearance of cyanosis It may be present in certain congenital cardiovascular malformations without indicating failure In acquired lesions cyanosis will be noted particularly in the presence of mitral stenosis tricuspid stenosis and with right sided failure in general It is very marked if due to extensive obliterative vascular disease in the lesser circulation Cyanosis may occur of course without any cardiac disease pulmonary hypoventilation or certain chemical poisonings may serve as examples

6 **Pulmonary Engorgement** Left sided failure or obstruction leads to engorgement of the venous half of the pulmonary circuit, and later this is followed by overfilling of the entire lung field Hypertension and organic defects of the left sided valve orifices may serve as examples The output of the left and right hearts are equal for some time and circulation takes place at a higher pressure level The outstanding symptom is dyspnea both of the exertional and paroxysmal variety Cyanosis cough,

hemoptysis and fine basal rales may or may not be present Signs for pulmonary engorgement are First the roentgenogram reveals the transparency of the lung fields diminished with occasional cloudy opacities all vascular shadows are increased in density and width but are relatively hazily outlined This holds particularly true for the hilus structures Second an accentuation of a previously normal second pulmonic sound *Third a decrease in the velocity of blood flow through the pulmonary circuit* this can be determined by measuring the arm to tongue and arm to lung circulation time

7 Venous Engorgement Right sided failure or obstruction leads to engorgement of the systemic veins An increase of the venous pressure to over 15 cm of water indicates then advanced insufficiency of the right side of the heart provided that pericardial and mediastinal pathology have been excluded Such insufficiency of the right heart may be primary in nature such as observed with emphysema pneumonoconiosis obliterative disease of the pulmonary arteries pulmonary embolism and organic defects of the right sided valve orifices Much more commonly however it follows failure or valvular lesions of the left side Signs for venous engorgement are cyanosis engorgement of superficial veins and increase in venous pressure swelling of the liver subcutaneous edema and ascites

The normal venous pulse both of liver and neck veins is a volume pulse and indicates dynamic events in the right atrium As one observes the movements along the neck veins in a healthy person in the recumbent position one easily notices a collapse which is ventricular systolic in time This collapse is due to the rapid inflow of blood into the previously emptied right atrium The caudad movement of the atrioventricular septum and the sudden drop of the intrathoracic pressure due to outflow of blood from the chest cavity favor this collapse The veins then fill gradually This ascent is broken by another collapse which occurs during the early part of ventricular diastole This collapse is due to the emptying of blood from the right atrium through the opened tricuspid valves and while it always is registered on the graph it may not be noticeable on gross inspection The progressive distention of the vein is then suddenly increased This indicates atrial systole which has interrupted the inflow of venous blood into the right atrial cavity *The normal venous pulse in the neck is therefore characterized by a systolic emptying and diastolic*

filling. Proper timing should be carried out by palpating the radial pulse while inspecting these pulsations.

With cardiac failure and mild congestion the veins reveal an increase in both fullness and pulsations. As congestion increases, the normally visible pulsations in the lower part of the neck disappear, while they become noticeable in its upper part; and pressure against the abdomen causes the level of pulsations to climb craniad. With maximal stasis, no movement may be noted in the very full veins, and pulsations may be only brought out as the patient gradually sits up or during deep inspiration. A closer observation of these pulsations reveals that the normally observed systolic collapse is lacking completely. That means that the ascent of the venous pulse, starting in early diastole, lasts throughout the systole Hence, one speaks of the systolic or ventricular form of the venous pulse. Obviously, the enhancing effect of ventricular contraction on the venous blood flow is diminished; and the overdistended and often fibrillating right atrium is emptied inadequately. A collapse from the high plateau occurs at the time of the opening of the tricuspid valves, which is during the early part of ventricular diastole. *Hence, this pulse is characterized by a diastolic emptying.* In the presence of tricuspid regurgitation there is likewise noted a diastolic collapse and a systolic elevation. But the latter is more impressive, abrupt, and, in contrast to the congestion pulse, well palpable.

A congested and large liver is likely to reveal pulsations of the ventricular type, particularly so in the presence of auricular fibrillation. The ascent of the pulse wave is not so distinctly felt, but rather the subsequent diminution in volume, *i. e.*, the diastolic emptying of the liver. This is also, and quite markedly, noted in the presence of adhesive pericardial disease. This is of diagnostic significance, because the condition, which is most likely to imitate adhesive pericardial disease, is tricuspid regurgitation. Here a liver pulse of the ventricular type is likewise found, but the outstanding feature is a sudden and forceful systolic thrust; while with ordinary congestion and adhesive pericardial disease the systolic filling of the liver takes place gradually. In the presence of sinus rhythm, and providing the right atrium is still capable of contracting forcefully, with the right heart overfilled or because of an associated tricuspid stenosis, an obstacle is offered to right atrial emptying. The blood is then backed up into the venae cavae during the presystolic period and a presystolic

regurgitation wave results. This is called the presystolic auricular liver pulse, *i. e.*, it is diastolic in time and its elevation distinctly follows the elevation palpated at the radial artery. In the presence of mitral stenosis such a presystolic liver pulse is highly suggestive of an associated tricuspid stenosis, though it may well occur in the presence of marked congestion with sinus rhythm preserved. Often the liver pulse reveals in addition to the presystolic regurgitation wave a systolic elevation. An associated tricuspid insufficiency or marked overfilling of the right atrium, such as noted in tricuspid stenosis or with the interatrial septal defect, may be responsible for it.

FIGURE 10. Male, aged 41. This obese patient had developed signs and symptoms of left ventricular failure with coronary artery disease and a mild hypertension as presumable etiology. A considerable degree of cardiac enlargement existed. During the course of one week the patient had been given an unknown amount of digitalis. The electrocardiogram (Lead II) reveals sinus rhythm which is interrupted by premature ventricular beats of multifocal origin and in bigeminus arrangement (1, 3) and a short run of ventricular tachycardia (2). These findings disappeared promptly upon discontinuance of digitalis and prescribing quinidine sulfate, 0.2 Gm. (3 grains), strychnine sulfate 1.6 mg. (1/40 grain), t. i. d. Bigeminal premature beats reappeared on digitalis medication but were not noted when all three drugs were given together. (Cyclopedia of Medicine, F. A. Davis Co.)

TREATMENT

Reversibility of Cardiac Enlargement: A discussion of treatment in this chapter will necessarily be very limited. Cardiac enlargement, as previously stated, signifies potential or actual insufficiency of the myocardium, and patients with a considerable degree of enlargement rarely ever possess good exercise tolerance. It is the duty of the physician, therefore, to *regulate the life of the patient* so that he will remain within the limits of his reserve, in order to avoid heart failure as long as possible. Such a limitation of activity may range from complete *bed rest*, as in the case of acute myocarditis, glomerulonephritis, or congestive failure, to a program of nearly normal activity, avoiding athletic activity and excessively long working hours, as in the case of a fully compensated rheumatic valvular lesion or benign essential hypertension. *Overweight* should be *reduced* and *excessive fluid intake avoided*, because these are an unnecessary additional strain for the circulation. *Digitalis* is first indicated when

the limitation of reserve becomes evident, together with simultaneous *curtailment of physical activity,* and, second, when auricular fibrillation supervenes, particularly in the rheumatic and sclerotic group

In the great majority of instances enlargement of the heart is a chronic incurable condition, particularly in reference to the large group of hypertensive, valvular, sclerotic, or syphilitic etiology.

In a relatively few instances it is possible to remove the cause of cardiac enlargement so that regression of heart size will occur, provided that not too long a period of time has elapsed and that no other complicating factors interfere. As examples may be cited: (*a*) Prolonged attack of paroxysmal auricular tachycardia (unilateral carotid sinus and bilateral bulbus pressure; induced gagging and vomiting; magnesium sulfate, 15 cc. of a 20 per cent solution, intravenously; quinidine sulfate, 0.4 to 0.6 Gm. (6 to 9 grains) orally, every four hours; mecholyl, 20 to 35 mg., subcutaneously, atropine sulfate is the antidote; digitalis, at least 3 cat units, intravenously, rectally or orally, to be repeated within a few hours); paroxysmal ventricular tachycardia (magnesium sulfate, quinidine sulfate, as above; but never digitalis); (*b*) thyrotoxicosis (*subtotal removal of the gland*); (*c*) myxedema (*thyroid medication;* resorption of pericardial fluid may also play a rôle in the reduction of "heart size"); (*d*) B avitaminosis (purified *B_1-vitamin* intravenously and orally and proper *diet*); (*e*) anemia of the pernicious or intestinal parasitic type (*liver,* intramuscularly); (*f*) arteriovenous fistula (operative closure).

In other instances, a considerable diminution in the heart size will be noticed, provided the natural course of the disease is favorable, though treatment may occasionally be helpful. To cite: (*a*) Acute glomerulonephritis with hypertension (here resorption of pericardial fluid may be a contributing element in the regression of "heart size"); (*b*) myocarditis of rheumatic fever, diphtheria, grippe, typhoid fever; (*c*) replacement of a previously slow heart rate (nodal rhythm, complete heart block) by a faster, normal heart rate; (*d*) pulmonary embolism (said to affect the right heart only).

In the hypertensive and hypertensive arteriosclerotic patient with evidence of left ventricular failure, one occasionally observes regression of heart size, as proven convincingly by proper radiologic study. We are not referring to patients in congestive failure, for here it is very difficult, if not impossible, to evaluate changes in heart size. Such patients should

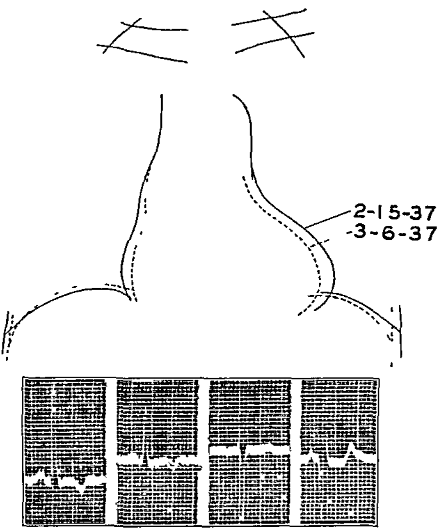

FIGURE 11 Male, aged 51 History Typhoid fever in past Heavy drinker and smoker Mild exertion and nocturnal dyspnea of very recent origin The findings were. W, 93.2 kg (205 pounds) sthenic habitus Trace of cyanosis no venous engorgement no *edema liver not enlarged* Cheyne Stokes respiration and a few pulmonary râles present Heart enlarged, at times gallop rhythm, other times embryonic rhythm very short systolic aortic murmur A_2 not unduly accentuated *B P varied from* 120/80 to 160/110 rate 90 One hundred mg per cent albumin in urine *Wassermann positive* Fundi Generalized attenuation of retinal arterioles with accentuation of reflex stripe no sclerosis ECG N s. r., P R 0 14 sec left axis deviation R to T segment in Leads I II and IV slightly depressed T inverted in Leads I and II in verted in IV positive (chest lead taken old way) Fluoroscopy and orthodiagrams *Ant view (solid line) Aortic configuration with moderate enlargement of left ventricular area*—L. 15.2 cm Aorta of adequate size. Lung fields reveal lesser degree of congestion no fluid at bases Rt ant obl view (no tracing) Left atrium slightly enlarged Treatment consisted of bed rest for one week *limitation of fluid intake to 40 ounces per day Theophylline ethylenediamine intravenously* and digitalis Follow up three weeks later Much improved—W 88.2 kg (194 pounds) Lungs clear Heart sounds normal B P repeatedly 125/70 rate 84 *Ant view* (broken line) Position of diaphragm reveals little change Width of lower chest slightly diminished silhouette smaller—L 13.8 cm. Lung fields clear Rt ant obl view (no tracing) Left atrium not appreciably enlarged Follow up The patient coöperated but little He gained in weight and there were transient periods of moderate hypertension Two orthodiagrams taken seven and nine months later revealed exactly the same heart size as shown in the first study Cardiac failure did not recur Two years later the man an executive was known not to have had any medical treatment He was active and about but was dyspneic and the family doctor reported the presence of basal râles A few months later a severe attack of left ventricular failure set in from which the patient recovered, but slowly

Comment An instance of hypertensive cardiovascular disease perhaps associated with syphilitic aortitis with episodes of left ventricular failure There was no pleural effusion no congestive failure in the greater circulation, no appreciable change in the position of the diaphragm The variations in heart size noted were actual changes and were not those apparent changes sometimes caused by pericardial effusion or changes in position

be given a trial with thiocyanate treatment, in addition to the medication and regime, as outlined above One may start out with a daily dose of 0 5 Gm (7½ grains) of the sodium or potassium salt of sulfocyanate, 4 cc (1 dram) of a mixture containing 5 Gm (1¼ drams) of the salt in 120 cc (4 fluid ounces) of aromatic elixir are given t. i d until the cyanate level in the blood has reached 8 to 12 mg per cent The dosage is then reduced and regulated in such a way as to maintain this blood

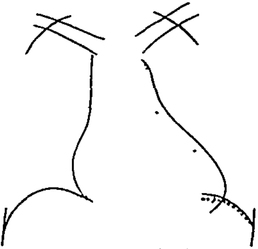

FIGURE 12 Male aged 22. The history revealed no disease except tonsillitis six months ago followed by tonsillectomy This healthy athlete had eight years of football baseball and hockey He felt fine was of a stout athletic build his height was 167.5 cm and his weight was 87.3 Kg (192 pounds) the chest circumference was 99 cm The apical thrust was just palpable 10.5 cm. to the left of the midline there was a short apical systolic murmur present which was not transmitted and there was no basal accentuation The heart rate was 72 per minute and the B P 138/82. Two tracings are shown The solid line was obtained during the training period and the dotted line after athletic activity had been discontinued for a period of four weeks the two orthodiagrams refer to a time interval of four weeks. The following were the respective orthodiagraphic measurements Width of chest 23 6 and 23.9 cm oblique diameter 15 7 and 14 1 cm broad diameter 10 4 and 9 7 cm.

Comment This case showed the regression of heart size following cessation of a severe training period It is very probable that the greater heart size was due to a stretching of muscle fibers rather than due to a thickening of the myocardium (Roesler Am J Roentgenol)

level It is definitely objectionable to use thiocyanates without having available such blood level determinations

It may be noted that in healthy athletes a moderate increase of the heart size may be observed during the period of severe training This takes about four to six weeks and recedes at about the same rate following cessation of training Whether the process underlying the increase in heart size is only due to a stretching of the muscle fibers, or whether there is also a thickening, is not known

Finally it may be asked how often and how much the heart recedes in size with recovery from congestive failure The change in the height of the diaphragm resulting from a diminution in the total bulk of the abdominal contents causes a change in the shape and position of the heart and this is a real obstacle in an evaluation on decrease in size both from a radiological and clinical point of view In addition resorption of pericardial fluid may introduce an element of error

CONCLUDING REMARKS

In closing this chapter it seems appropriate to stress a few points

There exists a growing tendency to shorten or replace careful clinical examination by the use of technical procedures and tests This should be *discouraged The taking of a good history and the meticulous inspection* and palpation of a patient are indispensable While radiology in many respects is superior to percussion it has not replaced it completely in addition it is not always available It is an unhappy and almost daily *experience to see erroneous electrocardiographic interpretations* such as Anterior cardiac infarction instead of left ventricular enlargement and strain often due to hypertension myocarditis instead of tracing commonly noted in the presence of postural circulatory deficiency myocardial disease instead of effect of digitalis medication etc *Both radiologic and electrocardiographic data require expert interpretation and should be always correlated with the clinical findings*

With the diagnosis of cardiac enlargement once established one should further investigate first what are the etiological factors second which heart chambers are affected and third what is the functional *capacity of the myocardium*

The diagnosis of early heart failure particularly of the common left heart failure is still not made often enough while acute cardiac dilatation being a very rare condition is still diagnosed too often

To make a diagnosis of cardiac enlargement involves quite a responsibility An erroneous diagnosis may unjustifiably withhold normal and healthy activity from a youngster may deprive a man and his family the benefit of a life insurance policy and may become for the patient most unnecessarily a source of anxiety and implant in him or her the seed of inferiority feelings But even if the diagnosis of cardiac enlargement is established beyond doubt it will be wise as a rule not to use this term

in conversing with the patient For what is a truth to the physician may be a nightmare to the patient

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CHAPTER XIX

CHRONIC VALVULAR HEART DISEASE

By JOSEPH B. VANDER VEER, M.D.

Introduction: The present-day approach to the study of heart disease has had a beneficial effect on all phases of the subject. The stressing of etiology has made diagnosis more accurate, prognosis more certain, and treatment more satisfactory. The tendency to consider especially the condition of the myocardium and the myocardial reserve has led to some disregard for chronic valvular disease. It is true that the valve lesion may be relatively unimportant in many instances, and that too much emphasis has often been placed on this subject in the past. However, chronic valvular disease still has an important place in the study of heart disease. Valvular defects are frequently contributing factors to cardiac failure and being common structural abnormalities, they must be considered in the differential diagnosis of heart conditions. A thorough knowledge of the signs of valvular defects is essential to good physical diagnosis. The type of valve lesion present may throw much light on the etiology of the cardiac disease and thus be of importance in the prognosis and treatment of a given patient. Murmurs from cardiac dilatation and noncardiac causes must be considered in the differential diagnosis of organic lesions of the valves.

Chronic valvular disease results mainly from four causes: Congenital abnormalities; "rheumatic" infections, syphilis, and atherosclerosis. Rarely it may follow acute or subacute infectious endocarditis. The condition is seen from birth to old age and about equally in the two sexes, when all ages are included. The highest incidence is seen in the colder climates where "rheumatic" infections are more frequent. The mitral valve is involved in over one-half of the cases. The aortic valve is next in frequency. Tricuspid disease is less common and involvement of the pulmonic valve is rare, being largely confined to congenital abnormalities.

The most frequent combination of valve lesions is mitral and aortic, with mitral and tricuspid disease being occasionally seen together Involvement of more than two valves is rare and the diagnosis is frequently a matter of conjecture

The ability to recognize the origin of murmurs is one of the most important factors in the diagnosis of chronic valvular disease Physicians with broad clinical experience have little difficulty with this matter in most instances, as the quality, location, and time of the murmur make its origin obvious Occasionally, however, other signs are necessary Evidence of enlargement of the right or left ventricle absence or accentuation of heart sounds, and changes in the pulse and blood pressure may give valuable information as to the lesion present With rapid or irregular heart action it may be necessary to accurately time the murmur to determine whether it occurs in the systolic or diastolic period Palpation of the carotid pulse while listening to the heart is the most reliable means and experience with this method in the more obvious cases soon gives one confidence The x rays and electrocardiogram are of secondary importance in most cases, though occasionally they may contribute information which is essential for establishing a correct diagnosis In general, apparatus for amplifying the heart sounds and for recording heart sounds and murmurs is of little practical value in clinical practice

MITRAL VALVE DISEASE

Etiology The mitral valve is frequently involved by disease processes In children and young adults rheumatic infections are practically always the cause A history of one or more attacks of acute rheumatic fever is often obtained but similar valvular disease may follow chorea scarlet fever and tonsillitis Occasionally no obvious etiologic factor is evident The female sex is more often affected (See also section on Rheumatic Fever) In elderly patients atherosclerotic processes may involve the mitral valve Syphilis does not attack the mitral valve and congenital disease is rarely a factor Relative insufficiency from dilatation of the mitral ring is of frequent occurrence in conditions which affect the left ventricle (hypertension aortic insufficiency etc)

Pathology The first change present in the rheumatic type is seen along the line of apposition of the valve cusps where small vegetations are aligned This is followed by thickening of the cusps and rounding

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of the clot breaking off from the auricular thrombus pass to the left ventricle and become the *emboli*, which may lodge in any part of the systemic circulation Infarction of the spleen kidneys extremities or brain may thus result

Pulmonary infarction is uncommon unless chronic passive congestion is present in the lungs With mitral stenosis this condition is frequent especially when the stage of cardiac failure is reached The emboli which plug the pulmonary arteries to cause the infarct may come from thrombi in the systemic veins (especially the lower extremities and pelvis) or from the right auricle At times arterial thromboses in the smaller pulmonary arteries may be the cause *Hemoptysis* in cases of mitral stenosis especially when the sputum is dark red and viscid is often due to this cause Pulmonary infarction usually is accompanied by pleuritic pain and blood spitting but in quite ill patients it may occur with a few clinical signs or symptoms and be an unrecognized contributory cause of death

Chronic passive congestion of the lungs and later of the liver are the rule with mitral stenosis Hepatic enlargement with even definite cirrhosis occasionally occurs and in long standing cases there may be splenomegaly A *frank* hemoptysis is less frequently the result of mitral stenosis than of either pulmonary tuberculosis or bronchiectasis Probably it occurs occasionally in the absence of pulmonary infarction (from a varix in the bronchial mucosa) but it is certainly not a common manifestation of uncomplicated mitral stenosis

Subacute bacterial endocarditis is nearly always superimposed on a previously *damaged valve* most *often an old rheumatic mitral or aortic valvulitis* Unfortunately this is more often than not a relatively mild lesion so that a patient who has been little incapacitated by cardiac disease must then be given a practically hopeless prognosis (See section on Bacterial Endocarditis)

MITRAL INSUFFICIENCY

This most frequent of all valvular lesions may be organic or relative

Signs Its characteristic sign is a systolic murmur in the region of the apex but it is important to remember that systolic murmurs in this area do not always mean heart disease The murmur may be soft or harsh in quality and short or long in duration It frequently accompanies

of the edges so the valve segments fail to close properly, causing an insufficiency. With further damage and scarring the cusp margins become adherent and the chordae tendineae thickened and matted to the cusps. A stenosis of the valve gradually occurs. As a rule the development of mitral stenosis is a slow process, extending over a period of several years. Occasionally it may develop quite rapidly, but probably rarely in less than two years The size of the orifice may gradually diminish so that eventually only a slit remains. Calcification is frequent in these long-standing and high-grades of stenosis.

With old age, atherosclerotic processes may attack the mitral valve, especially the aortic cusp, producing regurgitation. Rarely, calcium deposits may be present in the valve ring and extend into the base of valves producing a definite stenosis.

Enlargement of the left ventricle from any cause may produce dilatation of the muscular ring of the valve, and a relative insufficiency result. This is especially common in aortic insufficiency and in hypertension. Myocardial fibrosis secondary to coronary disease is another rather common cause. A relatively loud systolic murmur may be heard at the apex area as the result of such conditions, even though no organic changes are present in the mitral valve *per se*

Secondary effects of the valvular lesion are seen on the heart chambers and on other organs. With mitral regurgitation, hypertrophy and dilatation of the left ventricle and auricle may occur. With mitral stenosis, hypertrophy and dilation of the left auricle and right ventricle are seen, with later changes in the right auricle.

Thrombi in the auricles are more frequent in mitral stenosis than with any other valvular lesion, and especially so when auricular fibrillation is present. They usually begin in the auricular appendage, increasing in size until they may project well into the auricular cavity. Large thrombi are found occasionally free in the auricular cavity, and they may grow to considerable size and may even cause death by obstruction of the auriculo ventricular valve, the so-called "ball-valve" thrombus.

Emboli to the brain, viscera and extremities are more often seen with mitral stenosis and auricular fibrillation than any other type of cardiac condition. Because of the marked stasis in the left auricle from the mitral valve narrowing and failure of the auricle to contract, thrombus formation is especially frequent with this *combination*. Small or large particles

of the clot, breaking off from the auricular thrombus, pass to the left ventricle and become the *emboli*, which may lodge in any part of the systemic circulation Infarction of the spleen, kidneys, extremities or brain may thus result

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the first sound, seeming to replace it. Occasionally it may occur late in systole and be heard between the first and the second sounds. In these cases, if not timed carefully, it may be regarded as diastolic. Its point of maximum intensity is at the apex area or just lateral to it. Its transmission is especially toward the axilla. If very loud, it is often heard over the entire precordium and in the left scapular area. The pitch of the murmur is high and at times it has a musical character. It is heard easily with any type of stethoscope. A thrill is occasionally felt in the region of the apex. The second sound is frequently accentuated at the apex or pulmonic area, and may be reduplicated Evidence of enlargement of the left ventricle is often present. There are no symptoms characteristic of this lesion.

Diagnosis: In the diagnosis of mitral incompetency one must first eliminate systolic murmurs at the apex area, which are not the result of heart disease *Anemia, fever, hyperthyroidism and other factors increasing blood velocity may give systolic murmurs at the apex,* usually soft in character. Coincidentally, systolic murmurs are apt to be heard in the pulmonic area. Cardiorespiratory murmurs, which are heard during certain phases of respiration, but absent at other times, are a normal phenomenon. As Sir Thomas Lewis so aptly points out, a systolic murmur at the apex may be an important guiding sign and should stimulate one to look carefully for other evidences of heart disease. A careful search should be made for the characteristic murmur of mitral stenosis and for factors which may cause hypertrophy and dilation of the left ventricle. Levine has pointed out the importance of attempting to ascertain the cause of all systolic murmurs. With a moderately loud murmur at the apex organic heart disease is apt to be present and there are nearly always other signs of heart disease. The intensity and location of the murmur are of more importance than transmission in determining whether a given murmur is "functional" or not. The underlying condition, causing a "relative" mitral systolic murmur, may be more serious than that causing an organic valvular lesion, *i. e.,* hypertension, syphilis or myocardial damage from coronary disease It may be difficult to determine whether the valvular insufficiency is due to disease of the valve itself or to dilatation of the valve ring, or both. Fortunately, the prognosis and treatment are not altered by this academic problem, as they are based on other factors than the valvular insufficiency *per se.*

MITRAL STENOSIS

This important valvular lesion is frequently overlooked Many patients having it are *symptomless, and in those with symptoms the complaints* usually result from secondary effects of the condition

Signs: There are several signs which are suggestive of this condition Inspection of the precordium may show increased activity in the region of the lower sternum and left intercostal spaces especially the third and fourth Palpation of this area and the area of the apex beat often reveals evidence of increased activity and a *shock* synchronous with systole A diastolic *thrill* may be felt at or near the apex area and usually just preceding the systolic impact unless fibrillation is present when it *occurs early in diastole* *Percussion may be misleading as there may be* little or no evidence of cardiac enlargement demonstrable by this means The auscultatory signs are the most important

A *diastolic* murmur at the mitral area is the sign of greatest diagnostic value It is characteristically of low pitch and very localized It frequently has a rumbling quality and is heard best with the patient recumbent *In early cases it may be heard with certainty only with the patient turned on the left side* It is usually accompanied by a systolic bruit which gives a to and fro character to the murmurs With a well developed stenosis *the murmur is usually maximum in late* diastole and has a harsh *crescendo* character (the result of auricular systole) In these cases it frequently ends in a slapping first sound and it is often continuous with a systolic murmur In children the murmur may be soft in character and mid diastolic resembling a third heart sound at times With *auricular fibrillation* the murmur is altered in its time in diastole It tends to be maximum in early diastole when the auricular pressure is greatest With rapid and *moderate* ventricular rates the murmur extends *through to the next* systole but with slow rates the murmur may be exhausted before many of the following ventricular contractions Increasing the heart rate will usually increase the intensity of the murmur The murmur of mitral stenosis may disappear at times with failure and dilatation of the heart and even with the patient resting quietly in bed In the latter cases it reappears quickly with exertion and increase in the cardiac rate Other auscultatory signs of importance are *an accentuated snappy first sound at the apex* area and an accentuated or split second sound at the pulmonic area

The Austin Flint murmur, which occurs with about one-half of the cases with free aortic regurgitation, is identical in time and location with the murmur of mitral stenosis. It may be less harsh in quality and a definite thrill is rare. The first sound at the apex does not tend to be accentuated, but systolic murmurs at this area are frequent, as dilatation of the left ventricle is so commonly present in these cases. In many instances a differential diagnosis cannot be made on the basis of physical signs alone. The exact mechanism of production of this murmur is debated. Rarely, diastolic murmurs may be heard in the mitral area in cases of greatly enlarged hearts, with adherent pericardium and after pulmonary embolism.

Bland, White and Jones have pointed out the relative frequency of *diastolic apical murmurs* in children with active rheumatic heart disease without mitral stenosis, but with active myocarditis. The presence of such murmurs should make one suspicious of mitral stenosis, but final opinion should be reserved, especially if it is the first attack of rheumatic fever. The Graham Steell murmur of relative pulmonic insufficiency is so rare, even with extreme grades of mitral stenosis, that it is safer to consider murmurs of this type as arising from the aortic valve, even when there are no other signs of aortic insufficiency. (See Pulmonic Insufficiency.)

Auricular *fibrillation* is much more frequent with mitral stenosis than with any other valve lesion. This is probably related to the coincident strain placed on the auricles (especially the left) by the narrowing of the mitral valve. Most patients under 45 years of age with this arrhythmia have mitral stenosis.

Diagnosis: The diagnosis of mitral stenosis can be suspected frequently by palpation of the precordium. The presence of a definite systolic impact or shock in the apex area is always very suggestive and it may be present when there are no signs of cardiac enlargement. A diastolic thrill is of value when present, but is often variable and occurs only when the murmur is loud.

The diagnosis will seldom be missed if the characteristics of the murmur are known. In all cases in which a systolic murmur or snappy first sound are present at the apex, or the second sound is accentuated in the pulmonic area, an especially careful search should be made. In nearly a third of the cases of mitral stenosis little or no systolic murmur is present. It is in these patients that the lesion is most often overlooked.

especially if the patient is not recumbent A healthy suspicion is a valuable aid and in any questionable case examination after exercise with the patient prone and slightly turned on the left side will usually clinch the diagnosis A perle of amyl nitrite may be used in place of exercise to increase the heart rate

X ray studies of the heart are of considerable value in doubtful cases Fluoroscopic examination may demonstrate enlargement of the right ventricle (pulmonary conus area) and the left auricle which are strong confirmatory evidence for mitral stenosis

With free aortic regurgitation of obvious syphilitic etiology a diastolic murmur of rumbling character at the apex can be safely regarded as an *Austin Flint Murmur* *In many instances the final decision as to whether* one is dealing with mitral stenosis or a Flint Murmur can be determined only by a careful analysis of all data available and a period of clinical observation It is probably safer to reserve an opinion as to the presence of mitral stenosis in cases of active rheumatic heart disease until the infection has subsided and possible dilatation from myocarditis is relieved

The murmur of aortic insufficiency need not be confused with that of mitral stenosis The former occurs early in diastole has a blowing high pitched quality and its point of maximum intensity is usually along the left border of the sternum at the level of the third or fourth interspace Even with auricular fibrillation in which the murmur of mitral stenosis occurs early in diastole the character and location of it usually leave no doubt as to its origin The association of disease of the aortic and mitral valves is frequent in rheumatic heart disease but the signs of both lesions tend to be distinct

Case I A white boy 18 years of age was first seen in the Cardiac Clinic of the Pennsylvania Hospital at the age of 11 At the age of eight when seen by a physician for a multiple arthritis a rheumatic heart was discovered At the time of our first examination there were signs of definite cardiac enlargement and mitral insufficiency He was malnourished and his tonsils were enlarged and appeared infected

The patient was followed at intervals of two months during the next year Tonsillectomy was done without difficulty and he continued to attend school After about six months a slight diastolic and presystolic murmurs became evident at the apex area The loud apical systolic murmur remained There was no gain in weight during the year of observation and he complained of easy fatigue and dyspnea on slight

no essential change in the cardiac murmurs at the apex but a systolic murmur was now heard over the entire base of the heart No aortic diastolic murmur was noted on admission or on frequent subsequent examinations The B P was 110/90 Moist rales were heard at the right base posteriorly The abdomen was tender to palpation over the upper

FIGURE 1 Case I Left ventricle and mitral valve opened to show marked thickening and *contraction of the mitral valve cusps with shortening* and thickening of the chordae tendinae Note also the thick left auricular wall with thickened opaque and wrinkled endocardium The right ventricular wall is seen to nearly equal the left in thickness and there is an old adherent thrombus in the auricular appendage

quadrants and the liver edge reached nearly to the umbilicus The spleen was not felt but seemed enlarged to percussion Slight edema of the feet was present

The patient was redigitalized at once and the pain relieved by *morphin and codeine The ventricular rate was quickly controlled*, but

general improvement was slow and pain persisted in the splenic area The temperature was slightly but persistently elevated during this hospital admission but the heart and pulse rates fell quickly to around 60 per minute The electrocardiogram showed auricular fibrillation right axis deviation and abnormal T waves in Leads II III and IV He died suddenly and rather unexpectedly on the twentieth hospital day

Post mortem examination revealed some free fluid but no adhesions in the pericardial pleural and peritoneal spaces The heart was enlarged greatly weighing 490 Gm There was marked stenosis of the mitral valve with thickening of the valve cusps and chordae tendinae but no calcification (see Fig 1) A slight but definite triscuspid stenosis was present The aortic valve showed a definite old valvulitis of rheumatic etiology All three of these valves showed numerous small pinkish vegetations on the valve margins typical of acute rheumatic lesions The pulmonic valve alone remained free from the acute and the chronic processes The right and the left ventricular walls were both thickened especially the former and they measured 12 and 15 mm respectively The left auricle was hypertrophied and there was thickening of the endocardium with an attached ante mortem thrombus in one area The right auricle was much dilated The coronary arteries and their orifices were grossly normal Microscopically sections of the affected heart valve cusps showed marked scarring round cell infiltration and numerous Aschoff bodies The myocardium was hypertrophic with round cell infiltration and increased connective tissue but few Aschoff bodies were seen The lungs showed gross and microscopic evidence of long standing chronic passive congestion The spleen was about twice normal size and was adherent to the diaphragm over its upper one half which was made up largely of a healing infarct The liver was enlarged somewhat with a coarsely nodular surface Evidence of marked chronic passive congestion with an increase in connective tissue was present on the cut surface The other organs showed only evidence of long standing passive congestion

This case shows the gradual development of severe rheumatic heart disease in a boy with few of the articular manifestations of acute rheumatic fever Mitral stenosis resulted early in the disease and auricular fibrillation was established at a relatively early age (17) Marked hepatic enlargement occurred coincident with the development of congestive failure The finding of definite aortic and tricuspid valvulitis at post mortem when not suspected clinically is not very uncommon in severely damaged hearts with active infection The marked chronic passive congestion of the lungs was not accompanied by pulmonary infarction as is so frequently observed in these cases but an infarct of the spleen was

obvious clinically and confirmed at autopsy The embolus causing the splenic infarct, *no doubt, arose from the thrombus in the left auricular* appendage

AORTIC VALVE DISEASE

Etiology Disease of the aortic valve is second in frequency to that of the mitral valve It is more common in the male sex The cases may be divided roughly into three groups (1) Those in children and young adults are nearly all due to the rheumatic infections (2) Cases beginning in the period of middle life are due largely to syphilis (3) A few cases with aortic disease are seen in the old age group usually the result of atherosclerotic and degenerative processes Hypertension may or may not be present Patients are, of course, seen at times with combinations of the above etiologic factors Acute and subacute infectious processes attack this valve relatively frequently (See section on Bacterial Endocarditis) Rupture of an aortic cusp is a rare cause of aortic insufficiency and occurs practically always in a valve damaged by syphilis or bacterial endocarditis Relative aortic insufficiency is most uncommon because of the fibrous character of the aortic ring It is wise to regard all cases of aortic insufficiency as the result of organic changes

Pathology *Rheumatic* affections involve the cusps of the valve at the line of apposition, so that perfect closure is prevented Thickening of the cusps follows with adhesions at the commissures Insufficiency of of the valve is the first lesion produced With progression of the scarring process a slight or moderate stenosis may develop In long standing cases calcium deposits often occur, and the degree of stenosis may, at times be marked even in young adults In most cases of rheumatic aortic disease however, stenosis is not a factor clinically

Syphilis attacks both the aortic valve and the aorta itself It involves the valve cusps to a greater or less degree, producing thickening and rolling of the edges with often retraction of the cusps Dilatation of the fibrous ring itself is usually present with a widening of the commissures Aortic regurgitation is the lesion produced *Syphilis does not cause aortic stenosis,* a truth long known but still needing emphasis The systolic murmur present at the aortic cartilage in most of the luetic cases is the result of dilatation of the aorta from a coincident aortitis Syphilitic processes in the root of the aorta not infrequently encroach upon the mouths of the coronary arteries and may lead to or hasten myocardial

insufficiency Involvement of the root of the aorta occasionally occurs without concomitant valve disease

Atherosclerotic processes may involve the aortic valve to produce both insufficiency and stenosis The patients are nearly always old men and a severe grade of stenosis occasionally results Calcareous deposits are the rule beginning at the base of the cusps and extending into the valve and sinuses of Valsalva Breaks in the endocardium are frequent and thrombi may be deposited on these areas increasing the disability of the crippled valve Many pathologists believe that most of the cases of aortic stenosis seen in the old age group are the result of degenerative changes in previously damaged valves from rheumatism or healed infective endocarditis A few cases of acquired stenosis are seen in bicuspid aortic valves These valves were previously thought to be congenital in origin but recent studies suggest that bicuspid aortic valves in adults may be the result of old rheumatic processes

It seems logical that all cases of aortic stenosis must have some degree of insufficiency of the valve Clinically however the features of regurgitation may be very slight especially in the old age group where even the characteristic diastolic murmur may at times be absent

Secondary effects of aortic valve disease are often striking Many of the largest hearts seen are the result of aortic insufficiency, which causes both dilatation and hypertrophy of the left ventricle with later changes in the left auricle and entire right heart Aortic stenosis produces the classical examples of concentric hypertrophy of the left ventricle Extreme hypertrophy of this chamber may be present in these cases with little or no dilatation

AORTIC INSUFFICIENCY

Symptoms Subjective symptoms are more frequent with this valve lesion than any other Precordial distress of various types is common and palpitation is often distressing True angina pectoris may occur and is usually the result of a coincident aortitis

Signs Definite enlargement of the heart to inspection and palpation are frequent in aortic insufficiency The enlargement is predominately left ventricular and the apex beat of the heart tends to be localized and forceful It is usually displaced downward and outward from the usual area The two most important signs are a *diastolic murmur* at the base of the heart and an increase in the *pulse pressure* The murmur is of

great importance as it may be the first or only sign It has a high pitched blowing quality and is usually heard best along the left border of the sternum at the level of the third or fourth interspace It begins immediately after the second sound and frequently seems to replace it The second sound is usually not heard clearly in the aortic area (second right costal cartilage) *even though the murmur is not well heard in this area*

The murmur is usually of fairly long duration though in early cases it may be only a short whiff When the murmur is of slight intensity and short duration it may be overlooked unless the patient is examined in the upright position with the breath held in expiration The *diaphragm stethoscope is more sensitive than other types in detecting this murmur* When loud the murmur is heard in the aortic area and usually is accompanied by a systolic murmur giving a to-and fro character Its direction of transmission is toward the apex and it may be heard in the axilla Rarely the murmur may be heard *best* at the apex or just medial to it Occasionally the murmur of aortic insufficiency has a definite musical quality rather aptly compared to the cooing of a dove At post mortem examination most of these cases are found due to syphilis and there is seen a hinge like deformity of one of the valve cusps which vibrates with the regurgitation of blood The murmur in these cases may be loud enough to be heard by the patient or even at some distance from the chest This is the type of murmur described in cases of ruptured valve cusp but is probably much more frequently caused by the deformity just mentioned In either instance the onset is apt to be sudden and often with exertion With a very loud murmur usually musical in character a diastolic thrill may be felt at the base somewhat variable in location A systolic murmur at the apex as the result of relative mitral insufficiency is a common finding About half of the cases of free aortic regurgitation have an Austin Flint murmur at the mitral area (See Mitral Stenosis) It is apt to come and go without apparent cause and differentiation from organic mitral stenosis may be difficult

The second important sign is the *Corrigan or waterhammer pulse* This is the result of a large pulse pressure and is caused by the ejection of an increased amount of blood into an aorta having an unusually low pressure The quick rise and fall of the pulse wave is easily felt on palpation The increase in pulse pressure is responsible for the many sug

as the other signs of the mitral disease differentiate it from a murmur arising in the aortic valve Acute rheumatic pericarditis occasionally gives a soft to and fro friction at the base which is not unlike a murmur Careful observation over a few days will prove the true nature of the condition

AORTIC STENOSIS

There are no symptoms which occur as the result of this lesion Syncope and sudden death are more frequent with aortic stenosis than any other valve lesion but often a marked grade of stenosis is well borne even in the elderly *Some degree of insufficiency is present in all cases* In the old age group it is apt to be insignificant while in the cases resulting from rheumatic infections regurgitation features often predominate Aortic stenosis of a moderate or marked degree is a rare lesion and should be seldom diagnosed Actually slight degrees of aortic stenosis are not very uncommon in rheumatic heart disease because of the nature of the pathological process but these lesions seldom give sufficient signs to be positively diagnosed clinically

Signs The sign which usually calls attention to this lesion is a harsh systolic murmur at the base maximum at the aortic area It is usually transmitted upward into the neck vessels As similar murmurs *occur in other conditions it is of little diagnostic value alone* Occurring as it does in all cases however it arouses suspicion and should initiate a search for other more important signs A systolic thrill is nearly always present at the aortic area and is best felt with the patient upright and on expiration It is not absolutely essential for diagnosis and occurs occasionally in other conditions The effect of the stenosis on the pulse is one of the most important signs of the condition With well developed stenosis the pulse is *characteristically small and of good tension with a* slow rise and sustained quality the plateau or anacrotic pulse With a considerable degree of valvular insufficiency the pulse wave is of course altered To determine the relative effect of the two conditions on the pulse may not be an easy matter in some cases An equalizing effect on the blood pressure is seen when both stenosis and insufficiency are present so that at times the pulse and blood pressure are essentially normal The aortic second sound is usually not heard The murmur of aortic insufficiency is practically always heard, even though the signs of regurgitation are slight

Diagnosis It should be remembered that systolic murmurs in the aortic area are frequent, but that aortic stenosis is uncommon When the triad of murmur, thrill and plateau pulse are present the diagnosis may proceed without question In many cases of rheumatic aortic disease with considerable insufficiency a diagnosis of *probable* aortic stenosis can be made with a fair degree of accuracy even though the typical pulse changes are not present A loud systolic murmur in the aortic area may be seen in dilatation of the aorta from luetic aortitis or atherosclerosis An accentuated aortic second sound and the absence of a pulse change or of a diastolic murmur make the diagnosis of stenosis untenable in these cases The following case history illustrates a number of the important features of aortic stenosis

Case II A physician 71 years of age, was first told of a cardiac murmur at the age of 58 years when he was examined because of shortness of breath on moderate exertion After a period of five years of relatively good health he consulted a cardiologist because of substernal oppression which he noted on walking up an incline or on walking, following a heavy meal Mental upsets and excitement would also produce similar distress which was relieved promptly by 0 3 mg (1/ 0 grain) of nitroglycerin The family history was negative except for a younger brother with diabetes mellitus who suffered an attack of coronary thrombosis at 60 years of age The past medical history was entirely negative for illness related to heart disease

Examination at 63 years of age revealed evidence of cardiac enlargement mainly left ventricular and a loud systolic murmur over the entire precordium This seemed loudest at the aortic area but no thrill was present and no diastolic murmur could be heard The blood pressure was 118/68 in both arms and the rhythm was regular The lungs were clear and there was no hepatic enlargement. The extremities showed only a considerable thickening of the palpable arteries

During the next seven years the patient remained in good general health and he continued to do a great deal of important work His physical activity was limited by the anginal attacks but their frequency or severity showed little change, and relief from nitroglycerin was prompt At times the drug was used effectively for the prevention of attacks There was no appreciable change in the cardiac findings or blood pressure during this time The cardiac reserve became less and the anginal attacks were more easily induced during the few months prior to his death but he continued to lead an active and useful life He died suddenly while climbing the stairs in his home

Post mortem examination was limited to the heart and aorta. These structures together weighed 520 Gm The heart was not dilated but the left ventricular wall showed marked thickening due to hypertrophy This wall measured 18 mm and the right, 6 mm Marked stenosis of the aortic valve was present, the orifice being little more than a slit and the

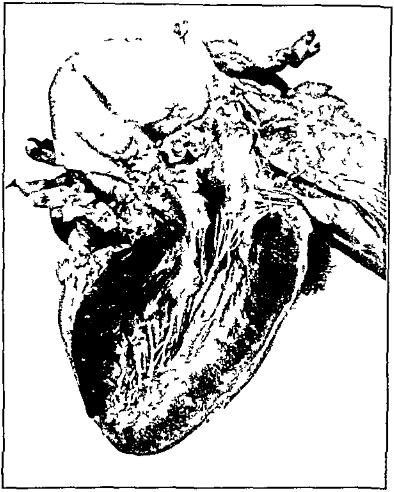

FIGURE 2 Case II Left ventricle opened to show the aortic valve Note the extreme hypertrophy of the left ventricular wall with little dilatation of the ventricular cavity The aortic valve shows extreme deformity from fibrosis and calcification but the mitral valve is essentially normal A break in the intima of the first portion of the aorta is evident

cusps were rigid and calcified (see Fig 2) The mitral valve showed only very slight thickening of the cusps, and the chordae tendineae were normal The tricuspid and the pulmonic valves were not abnormal The coronary orifices were diminished in size by atherosclerotic processes in the aorta and there was a moderate degree of sclerosis with areas of calcification throughout the main coronary arteries No occlusion of the coronary

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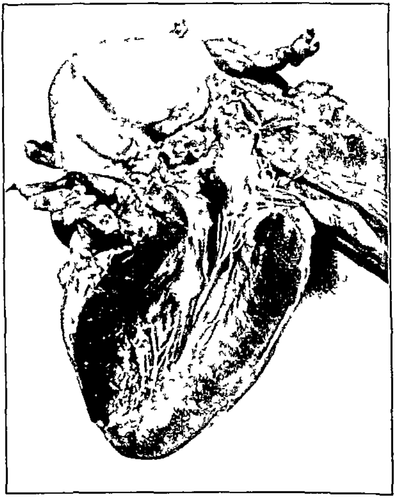

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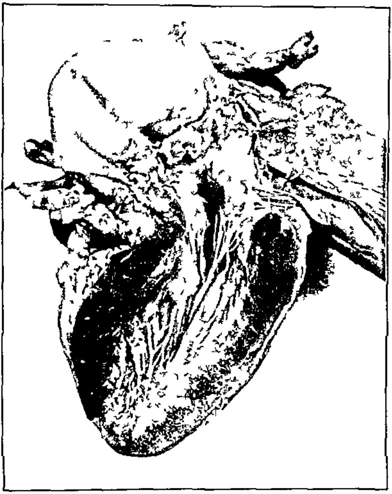

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arteries was demonstrable and there were no areas of myocardial infarction Microscopically there was hypertrophy of the muscle fibers but very little scarring Definite bone formation was present in the aortic cusps in addition to the marked deposition of calcium

This case of aortic stenosis was not classical in many of the clinical features but it illustrates well the fact that a high degree of aortic stenosis is often well borne especially in the older age group No systolic thrill or diastolic murmur was ever found and the patient was examined carefully by more than one competent cardiologist The blood pressure was not significantly altered The angina present was no doubt secondary to the coronary orifice involvement or to the coronary sclerosis or both The sudden death probably during an anginal attack (ventricular fibrillation?) is not uncommon with this condition It seems most likely that this patient belongs to the group of aortic stenosis cases which result from atherosclerotic and degenerative changes in the valve ring and cusps

TRICUSPID VALVE DISEASE

Well developed organic disease of the tricuspid valve is uncommon though functional dilatation of this valve is relatively frequent The causes of tricuspid endocarditis and the pathological changes are identical with those of mitral endocarditis The condition practically always is associated with mitral disease Slight valvulitis is not very infrequent at post mortem examination of patients dying with severe active rheumatic heart disease

Tricuspid Insufficiency as the result of dilatation of the valve ring is commonly present in congestive heart failure from any cause. A systolic pulsation in the veins of the neck may be visible and a systolic murmur maximum over the lower sternum is suggestive of tricuspid origin Coincident mitral insufficiency is the rule and the two murmurs may be difficult to differentiate Though relative insufficiency of this valve is probably frequent a distinct murmur is not common From the standpoint of prognosis and treatment the condition is of little or no importance

Tricuspid stenosis is a rare lesion and seldom diagnosed ante mortem Its most characteristic sign is a murmur similar to that of mitral stenosis but located at the lower end of the sternum Mitral stenosis is practically always present and aortic disease is not uncommon Marked dilatation of the right auricle is to be expected Absence of the characteristic murmur does not rule out the lesion The combination of cyanosis slight jaun

dice, pulsation of the neck veins and an enlarged pulsating liver are suggestive of tricuspid valve disease. These symptoms are especially significant if they exist in the absence of peripheral edema. The x-rays and electrocardiograph are of little value in the diagnosis of tricuspid disease, as lesions of this valve do not occur independent of other valve involvement.

PULMONARY VALVE DISEASE

The pulmonic valve is least often the site of acquired disease and most frequently the site of congenital lesions. The pulmonic area, however, is frequently the site of murmurs, both systolic and diastolic, and of cardiac and extracardiac origin. Systolic murmurs are especially common, and this area is the usual site of "functional" murmurs so frequent in children. With anemia, fever, or tachycardia, a systolic murmur localized to this area is relatively common. The cardiorespiratory murmur may be heard best here.

PULMONIC INSUFFICIENCY

This lesion as an isolated phenomenon is rare. Slight involvement of the cusps by rheumatic endocarditis is seen occasionally at post-mortem examination in cases with severe infection. As a rule in these cases, there is involvement of all of the heart valves, and the pulmonic valve disease is the most recent and least marked. *Isolated* pulmonic insufficiency is usually associated with dilatation of the pulmonary artery and its branches, and often with marked atherosclerosis of these vessels. The lesion is probably of congenital or developmental origin in most cases. *Relative* insufficiency occurs occasionally. The Graham Steell murmur is of this type, but it is seen rarely even with high grades of mitral stenosis. The murmur is seldom persistent in these cases.

Signs: The signs of pulmonic insufficiency are those of regurgitation into the right ventricle. The murmur is nearly identical with that of aortic insufficiency, though it is usually maximum at a slightly higher level (second left interspace). The usual signs of left ventricular enlargement and increased pulse pressure with associated phenomena, which are expected with aortic insufficiency, are absent. Evidences of right ventricular enlargement are to be expected, and x-ray and electrocardiographic studies may give valuable confirmation of this (in the absence of mitral or pulmonic stenosis). The pulmonary artery may be greatly increased in size with unusually active pulsations on fluoroscopic examination.

Diagnosis Relative pulmonic insufficiency secondary to marked mitral stenosis is a rare condition The murmur (*Graham Steell*) is practically identical with that of aortic insufficiency Even with a high degree of mitral stenosis and no other signs of aortic insufficiency a murmur in this area is probably more apt to arise from the aortic valve than from the pulmonic With evidence of involvement of the mitral tricuspid and aortic valves in severe rheumatic heart disease, the pulmonic valve may also be diseased The diagnosis in these cases is usually a matter of conjecture and certainly of no more than academic interest *Isolated* pulmonic insufficiency however occasionally can be diagnosed clinically The presence of a high pitched blowing murmur replacing the pulmonic second sound best heard along the left border of the sternum maximum in the second left interspace should suggest the possibility of this lesion if there are no signs of aortic insufficiency Evidence of enlargement of the right ventricle (without mitral or pulmonic stenosis) and a normal left ventricle make the diagnosis highly probable The electrocardiogram shows right axis deviation and fluoroscopy demonstrates enlargement of the right ventricle without evidence of left auricular enlargement Increase in the *size* and *pulsation* of the *main pulmonary arteries* usually is demonstrable The author has seen three cases of this type in which a diagnosis of isolated pulmonic insufficiency could logically be made clinically In all of these patients heart disease was known to have been present for a long period and two were in severe congestive failure when first seen Post mortem examination done in two of the cases confirmed the diagnosis One of the patients survived an attack of pneumonia for which he was hospitalized and complete studies after recovery confirmed the impression of pulmonic insufficiency

PULMONIC STENOSIS

This is one of the commonest and most important of the lesions of congenital heart disease The patients often live many years and may reach adult life The obstruction may be at the valve itself with narrowing due to thickening and adhesions of the cusps More often it is the result of an arrest of development in early embryonic life with failure of the infundibulum to fully expand The opening may be so small as to barely admit a probe High grades of stenosis are usually associated with other congenital malformations the commonest being a defect in the inter

ventricular septum and dextro-position of the aorta (*tetralogy of Fallot*) The cardiac signs are usually quite typical in a well-developed case A loud rough systolic murmur is heard in the pulmonic area usually accompanied by a thrill The murmur is not transmitted into the great vessels but may be heard over a relatively wide area and in the left inter scapular area The pulmonic second sound is absent and an early diastolic murmur is heard occasionally Evidence of right ventricular enlargement is usually present clinically and the x rays and electrocardiogram will usually give valuable confirmatory evidence of this finding Cyanosis is a feature in nearly all cases (due to the admixture of venous and arterial blood) and polycythemia and clubbing of the fingers are seen in the long standing cases The implantation of acute or subacute bacterial infections on the diseased valve is not uncommon For a more complete discussion of pulmonic stenosis and associated lesions see the section on Congenital Cardiac Abnormalities

PROGNOSIS OF CHRONIC VALVULAR DISEASE

The prognosis of patients with valvular disease is an individual problem and each case must be judged on its own merits The underlying cause of the valve defect is usually of greater importance than the lesion itself and this thought is well crystallized by Sir Thomas Lewis in the following statement It is probable that the reason why valve disease is significant is not to be found mainly in the burdens which it imposed upon the muscle but mainly in associated disturbances that come with the valve disease and from a common source The reserve of the heart is great and the extra work imposed by valvular lesions is usually relatively small The valve lesion *per se* only assumes the chief significance when other signs of heart disease are absent and in these cases the prognosis is usually good When cardiac enlargement or signs of failure are present these at once assume the major importance in prognosis

The present-day tendency to stress etiology in heart disease has had a salutary effect on prognosis It is obvious that the outlook for a patient with aortic insufficiency as the result of an old rheumatic infection is entirely different from that of a patient with a similar lesion caused by an active syphilitic process In rheumatic heart disease the prognosis must be based on other factors than the valve lesion in most cases The heaviest mortality in this group is from 15 to 30 years of age and less than one half

with actual previous experience some degree of accuracy in prognosis can be hoped for

TREATMENT

There is no specific treatment for chronic valvular disease *Fortunately, the day has passed when the presence of a murmur was thought to be an indication for bed rest or drug therapy* The more accurate etiologic diagnoses of the present day have aided in the promotion of better therapy in cardiac disease but with the actual cause of many of the disease processes still unknown our treatment is still symptomatic in most of the cases

In patients with organic valve disease but with little cardiac enlargement or impairment of cardiac reserve ordinary activity and exertion should be allowed Moderate exercise may be beneficial in these patients but of course strenuous exertion should be avoided Removal of all foci of infection is indicated especially in the younger patients Much can be done by prophylaxis and proper hygiene to conserve the myocardial reserve of these patients and thus prolong life Syphilitic heart disease can be prevented by the proper treatment of early syphilis With well advanced syphilitic cardiovascular disease treatment is of little avail though considerable improvement may follow therapy if the diagnosis is made early

The development of symptoms and signs of early cardiac failure in chronic valvular heart disease is the indication for immediate diminution in activity or bed rest and usually for digitalis therapy The treatment of this problem as well as the various disturbances in rhythm which may occur are discussed in detail elsewhere in this volume

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survive the fortieth year A minority (25 to 35 per cent) have a minimal lesion which remains inactive and they live a normal life span With recurrent attacks of rheumatic infection or long standing low grade activity, the prognosis is not good, though exceptions are seen Auricular fibrillation which is so frequent with mitral stenosis, is an unfavorable sign It tends to occur late in the disease, and while duration of life after its onset is variable, it is seldom more than a few years Embolism causes a fatal termination in about ten per cent of the cases of rheumatic heart disease with mitral stenosis and auricular fibrillation Multiple valve lesions themselves exert little effect on the prognosis, though indirectly, by increasing cardiac enlargement or representing, as they may a more severe infection, they may alter somewhat the outlook in the individual case

The prognosis is better in those patients who develop cardiac failure with auricular fibrillation and a rapid ventricular rate than in those with a similar degree of failure with a slow ventricular rate or normal sinus rhythm All things being equal, the larger the heart the poorer is the prognosis

Other conditions may occur with or be superimposed upon chronic valvular disease and greatly alter the prognosis In patients of the middle and older age groups coronary disease and hypertension are often factors which make the outlook unfavorable Luetic aortitis by encroachment on the coronary orifices may promote myocardial insufficiency in cases which might otherwise remain compensated Subacute bacterial endocarditis, a fatal complication of valvular disease which cannot be foreseen, accounts for about five per cent of the deaths in rheumatic heart disease Hyperthyroidism, if mild, may exist unnoticed with valvular heart disease and may cause cardiac insufficiency in patients who otherwise would be well compensated The diagnosis of the condition is thus of great importance as elimination of the thyrotoxicosis may restore the patient to relatively good health

In general then, it is seen that the valve lesion alone contributes but little to the prognosis of the average case of chronic valvular heart disease It does, however, point the way to a careful study of the etiological agents concerned, the degree of enlargement, myocardial reserve, and possible complicating factors By a careful evaluation of these factors coupled

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CHAPTER XX

CORONARY ARTERY DISEASE

By Fred M. Smith, M.D.

Introduction: The present discussion is concerned with the cardiac disability resulting from arteriosclerosis of the coronary arteries and primarily dependent on an inadequate blood supply to the myocardium. This is the most important form of heart disease and is the leading cause of death after 50 years of age. The clinical manifestations are necessarily varied because of the extent and distribution of the insufficiency of the coronary circulation and whether this is produced by gradual or abrupt closure of one or more of the main branches of the coronary arteries. The frequent association with involvement of the arteries elsewhere may further complicate the picture

Anatomy: In the discussion of the anatomy of the coronary arteries, only those features will be considered which are regarded as essential to the above objective. The reader is thus referred to the works of *Gross,[1] Spalteholz,[2] Campbell,[3] and Whitten[4] for a more detailed* discussion of the subject.

The blood supply to the heart is provided by two arteries The right coronary and the left coronary.

The right coronary artery arises from the anterior sinus of Valsalva It proceeds to the right and follows the groove between the right auricle and right ventricle to the posterior aspect of the heart, usually extending beyond the interventricular septum and terminating in descending branches to the mesial posterior wall of the left ventricle. Descending branches are given off to the anterior, lateral, and posterior walls of the right ventricle, and to a posterior segment of the interventricular septum, in addition to those which may extend to the posterior wall of the left ventricle. Important branches go to the auricles, which will be mentioned later in connection with the blood supply to the conduction

system This artery is then responsible for the major portion of the blood supply to the right ventricle, a posterior section of the inter ventricular septum, and frequently to an area of varying extent of the posterior wall of the left ventricle adjoining the interventricular septum It also contributes to a very significant extent to the arterial supply of the auricles, particularly the right, and to the conduction system

The left coronary artery arises from the left anterior sinus of Valsalva It passes downward and to the left, behind the root of the pulmonary artery, and soon divides into two main branches, the circum flex and the anterior descending branch

The anterior descending branch proceeds downward along the anterior aspect of the interventricular septum around the apex and terminates in twigs which are in close proximity to the terminal rami fication of the descending interventricular branch from the right coronary artery or from circumflex branch of left coronary artery This artery gives off lateral branches to the anterior and apical region of the left ventricle and to a small adjoining section of the right ventricle In addi tion, numerous branches penetrate the interventricular septum, almost at a right angle

The circumflex branch of the left coronary artery follows the groove between the left auricle and ventricle to the posterior aspect of the left ventricle, where it terminates in descending branches In some instances, it may continue even beyond the interventricular septum posteriorly During the course of this artery, branches are given off to the auricles and to the anterior lateral and posterior wall of the left ventricle The left coronary artery, through its two main branches, is, therefore, responsible for the arterial supply to the greater portion of the interventricular septum to a small area of the right ventricle adjoining the apex and to the left ventricle except possibly for a section of the posterior wall mentioned in connection with the right coronary artery It will thus be seen that while the right coronary artery com monly crosses the interventricular septum posteriorly and takes in a section of the left ventricle, the left coronary artery, through the anterior descending branch, extends over on the anterior wall of the right ventricle

1 *Conduction System* The sinus node is supplied by the ramus ostei cavae superior which is ordinarily one of the early branches of

the right coronary artery but which may originate from the circumflex branch of the left coronary artery. The above artery anastomoses freely with posterior auricular branches from both the right and left coronary arteries. The auriculo-ventricular node and the bundle of His have a special blood supply through the rami septi fibrosi arising from the right coronary artery near the posterior interventricular septum. The rami septi fibrosi likewise have free anastomosis.

The right limb of bundle apparently has a fairly definite blood supply through the early septal branches of the left coronary artery. The left limb is different in that it soon divides and spreads out under the endocardium of the left side of the interventricular septum and probably receives blood from a number of the numerous septal branches.

2. *Anastomosis.* The anastomosis between adjacent arteries in the normal heart apparently occurs for the most part by means of smaller branches or perhaps may exist only in the potential state until there is need for it. With the gradual closure of one or more of the main branches, however, there frequently develops free communication between these arteries and those in the immediate vicinity. Under these circumstances the subsequent obstruction by thrombus may result in very little degenerative changes in the myocardium. Thus it would seem that the rate of occlusion determines in a large measure the extent of the collateral circulation and the latter in turn is responsible for the fact that the heart is not infrequently able to withstand one or more major insults to the circulation. *Under adverse circumstances the blood supply to the myo*cardium may be enhanced by other means. Wearn and his associates have shown that the thebesian vessels may be a significant factor. Finally, Beck and Tichy[6] and Robertson[7] have demonstrated that in the presence of pericardial adhesion vessels from contiguous structures may *extend to the heart.*

Pathology. Arteriosclerosis of the coronary arteries is invariably associated with similar changes elsewhere and is frequently a part of a general involvement of the arterial system. The arterial changes are apt to be more advanced in certain organs as in the heart, brain and kidneys. *There likewise are varying degrees of aortic sclerosis.* Not infrequently, however, the alterations in the coronary arteries are more advanced than those seen in the aorta. In syphilis, on the other hand, the damage to the aorta is the outstanding feature and rarely are the coronary arteries

involved except by an encroachment on the ostia through an extension of the aortic process.

Minor changes in coronary arteries are rarely responsible for a significant impairment in the cardiac function unless by chance there is a coronary occlusion. The sclerosis of the coronary arteries, on the other hand, is more apt to be out of proportion to the clinical manifestations. Pathologists have frequently commented on this discrepancy. Kretz,[8] in his study of 106 cases, found no parallel between the clinical history and the anatomic findings. In 6 of the 16 cases with advanced sclerosis and narrowing of the lumen of the arteries, there was no mention of clinical symptoms during life. Only four had definite evidence of cardiac failure. Morawitz and Hochrein[9] have recently studied the autopsy findings in 91 cases of coronary sclerosis. In 75 per cent of these there were no subjective symptoms of cardiac disease.

In the more advanced forms of arteriosclerosis, nodular thickenings of the intima project into the lumen and produce varying degrees of occlusion. A complete occlusion frequently results through a gradual extension of the process or from a thrombus. Certain of the smaller branches are likewise eliminated. This particular feature is demonstrated in a striking fashion by injected specimens, in which certain of the small branches have the appearance of being nipped at the point where they leave the parent vessel.

It is generally recognized that the arteriosclerosis is usually more advanced in the anterior descending branch of the left coronary artery. This no doubt accounts for the frequent occlusion of this vessel. Whitten[4] has called attention to a similar involvement of the terminal descending branches of the right and of the circumflex branch of the left coronary artery and states that occlusion of these vessels frequently occurs and is often overlooked. This author comments on an interesting anatomic feature of the above vessels which he believes may contribute to the development of the arteriosclerosis. He points out that the branches of these arteries immediately penetrate the cardiac musculature at almost a right angle, and suggested that the immobilization produced by the method of branching promotes tortuosity, and possibly leads to a kinking or constricting of the lumen.

The changes in the myocardium range from the small areas of fibrosis resulting from the elimination of smaller arterial twigs, which

may be detected only by the microscope to the extensive fibrosis and necrosis induced by the occlusion of a larger artery In the latter, the extent of the damage depends on the degree of anastomosis and whether or not the occlusion is sudden or gradual The response of the heart to a coronary accident is thus determined in a large measure by the extent and the opportunity for the further development of the collateral circulation If a vessel is gradually occluded and the neighboring artery which contributes to the blood supply of this section of the cardiac musculature is not involved conditions are most favorable to the further development of the collateral circulation Under these circumstances more and more of the arterial supply to the particular section of cardiac musculature is taken over by the second vessel and the complete occlusion of the first even though abrupt may be followed by a surprisingly satisfactory recovery or possibly may not be suspected during life

The changes in the cardiac musculature are confined for the most part to the left ventricle In the earlier stages these may be represented by small isolated areas of fibrosis resulting from the obstruction of the small branches and perhaps supplemented by the gradual reduction in the lumen of certain of the larger vessels With the extension of the arteriosclerotic process a diffuse fibrosis may be produced This is usually associated with extensive sclerosis and stenosis of the coronary arteries with or without occlusion of one or more of the larger vessels In many instances the chief lesion is represented by a large area of fibrosis from the occlusion of one of the main branches of the coronary arteries The most common and characteristic of this type of lesion results from the closure of the anterior descending branch of the left coronary artery It involves the anterior apical wall of the left ventricle the lower anterior section of the interventricular septum and occasionally to a limited extent the apical portion of the right ventricle Infarctions of the lateral portion of the left ventricle are usually caused by the occlusion of the circumflexed branch of the left coronary artery whereas lesions of the posterior wall generally follow the obstruction of the right coronary artery The infarctions of the lateral and posterior walls of the left ventricle are commonly represented by a more patchy fibrosis than that observed with this type of lesion of the anterior wall The damage to the endocardium frequently leads to the formation of mural thrombi often involving both ventricles Extensive degeneration of the myo

cardium may result in rupture and cardiac compression from hemorrhage into the pericardium or later in the formation of an aneurysm of the left ventricle. The latter more often involves the anterior and apical region of the left ventricle. If the infarct extends to the epicardium, a localized area of pericarditis is produced, with the resulting formation of adhesions.

In coronary artery sclerosis, the changes in the papillary muscles and the mitral valve structures are an important feature. In the series of necropsies studied by Willius and Brown,[10] the mitral valves were damaged in 44 (51 per cent) of the 86 cases. The papillary muscles are commonly involved by the occlusion of either of the main branches of the left coronary artery and in rare instances the damage is so extensive that one breaks. The changes in the above structures contribute to the alteration of the first sound at the apex and the production of the systolic murmur frequently heard in this location.

In addition to the above changes in the myocardium, there are usually varying degrees of cardiac hypertrophy. There, however, is no definite relationship between the extent of the cardiac hypertrophy and the degree of coronary sclerosis. An advanced sclerosis of the coronary arteries is not infrequently seen in a normal sized heart. In the most extensive cardiac hypertrophy, on the other hand, the larger coronary arteries at least may not show significant changes. The latter characteristic is frequently observed in the hypertension form of heart disease, particularly after the onset of cardiac failure.

Symptoms: It is well to bear in mind that the cardiac disability in coronary artery disease is primarily dependent on an inadequate circulation. Thus, the clinical manifestations are extremely varied, depending on the extent and distribution of the insufficient blood supply to the myocardium and whether this is produced or supplemented by the gradual or sudden closure of one or more of the larger vessels. The clinical course may be further influenced by a hypertension or the development of symptoms from an arteriosclerosis involving other organs. The onset, therefore, may be very insidious or extremely abrupt, as in coronary occlusion. In certain instances, sudden death is the first intimation of the disease, whereas others may live for years after the appearance of the first symptom. Occasionally, the onset is overshadowed or perhaps masked by manifestations directing attention to some other organ

The appearance of premature contractions or the occurrence of paroxysms of auricular fibrillation, which later become permanently established, may be the first indication of an impaired cardiac function. In many, however, the first symptom is that of shortness of breath or the consciousness of a substernal discomfort on exertion. The frequent association of the latter with upper abdominal discomfort often convinces the patient that he has a gastric disturbance. Oftentimes coronary occlusion is the first evidence of a cardiac disability. In some of the latter the initial manifestation is that of intense dyspnea. The onset may follow an acute upper respiratory infection complicated by a bronchitis which persists longer than usual. Frequently, the onset is precipitated by overexertion or some unusual departure from the ordinary habits of living. The tendency of individuals above 55 years of age to overestimate their physical ability is often responsible for irreparable cardiac damage.

The study of Fitzhugh and Hamilton[11] is of particular interest in this connection and has a significant bearing on the general management of coronary artery disease. These observers succeeded in obtaining sufficient detailed records in 100 cases of angina pectoris or coronary occlusion to permit a rather careful study of the events preceding the fatal attack. They found that in a very high percentage of their cases there was a history of unusual physical exertion, prolonged activity resulting in excessive fatigue, persistence in activities that had repeatedly precipitated the angina, emotional strain, loss of sleep, dietary indiscretion, acute infections, or alcoholic excess. The demonstration by Leary[53] that coronary occlusion commonly results from the rupture of an atheromatous abscess provides a plausible explanation for the frequent occurrence of this condition following factors which place an extra strain on the cardiovascular system.

The commonest clinical picture is that of the congestive type of cardiac failure with the subsequent development of peripheral edema. In many of these there is at no time significant cardiac pain. In some, a history of angina may be obtained. This feature, however, is often overshadowed by the shortness of breath and not elicited except by direct question. There is another group in which the picture is that of angina pectoris. In the beginning, there may be no appreciable shortness of breath. Later, however, during the height of the distress, it frequently

becomes more prominent In some the picture is terminated by an attack of angina pectoris or coronary occlusion Others pass into congestive failure either through a gradual progression of the cardiac disability or possibly because of a coronary occlusion and the angina may disappear Finally there is a fairly large group in which the clinical picture is that of coronary occlusion

In a series of 86 necropsies studied by Willius and Brown[10] 21 (24 per cent) had angina pectoris without other symptoms of cardiac failure This group had extensive sclerosis of the coronary arteries and in 14 (66 per cent) there was pronounced occlusion of the vessels In 22 of the 86 the clinical picture was that of progressive myocardial failure without pain The extent of the sclerosis of the coronary arteries in this group was not as marked as in those with angina pectoris and only five had a significant reduction in the lumen of the vessels In the remaining 34 (40 per cent) the symptoms were not sufficient to make a diagnosis of coronary artery disease The sclerosis of the coronary arteries in the latter group was still less than that observed in the former These findings are in general accord with the observation of Nathanson[12] on the autopsy finding of 113 fatal cases of coronary artery sclerosis In 80 per cent attacks of angina pectoris or less often acute respiratory distress were the outstanding clinical manifestations while in the remaining 20 per cent the symptoms were those of a progressive cardiac failure without pain The sclerotic changes were advanced in all instances but the incidence of occlusion was highest in those who had angina pectoris

In a series of 420 cases analyzed by Smith Rathe and Paul[13] the initial symptoms were recorded as follows Shortness of breath in 189 (45 per cent) paroxysmal dyspnea in 35 (8 3 per cent) severe anginal pain indicative of coronary occlusion in 91 (21 7 per cent) angina pectoris in 87 (18 3 per cent) and pain in the chest or epigastrium of an indefinite nature in 28 (6 6 per cent) Pain and dyspnea were frequently combined to a varying extent in those with coronary occlusion In these cases the dominant symptom was listed as the initial complaint The subsequent developments were quite similar in the various groups varying only in the incidence of the above manifestations In the vast majority further progress of the cardiac disability was evidenced by either angina of effort attacks of severe anginal pain (typical of coronary occlusion) paroxysmal dyspnea or combinations of these When

admitted to the hospital, 199 (47.6 per cent) had congestive failure, 102 (24.3 per cent) angina of effort, and 62 (14.7 per cent) a recent coronary occlusion. According to the clinical interpretation, 311 (74 per cent) had had an occlusion of one of the larger vessels. Of these it was concluded that there were 105 (25 per cent) in which more than one of the larger branches had been obstructed.

Eighty-five of this series of patients died while in the hospital and 44 came to necropsy. In those coming to necropsy there was in every instance a disseminated fibrosis from the occlusion of the smaller branches. The clinical study justified the diagnosis of an occlusion of one or more of the larger branches in 26 instances, whereas at necropsy this condition was found in 28 cases. In the two in which the diagnosis was *not made before death, the onset was with paroxysmal dyspnea*

The physical findings are extremely variable. There is frequently a hypertension or the history of an elevated blood pressure. In those with hypertension, there is invariably a significant increase in the size of the heart This is more apt to be a prominent feature in those with congestive failure. In many of these, a hypertension has no doubt been a very important factor. Various forms of cardiac irregularities, particularly *premature contractions and auricular fibrillation, are common* findings. While auricular fibrillation is rarely associated with angina pectoris, it is frequently responsible for the onset of the congestive type of failure Auricular flutter and heart block (Adams Stokes attacks) are occasionally observed A muffling of the first sound at the apex, gallop rhythm, and perhaps a faint systolic apical murmur may be the outstanding auscultatory findings. The first sound is occasionally accentuated or *slightly rough* At other times there is a well-developed systolic murmur at the apex, which may be soft, blowing, harsh, or even musical in character. If auricular fibrillation is present, the first sound at the apex varies in intensity, and when the rate is particularly rapid, it is apt to be choppy. The associated systolic murmur likewise varies in intensity from cycle to cycle. The aortic second sound is usually accentuated and occasionally slightly emphoric. There is often a faint systolic murmur which is transmitted to the vessels of the neck. This murmur is seldom rough except when there is calcification of the aortic valves Occasionally a faint diastolic murmur is heard. However, if there is a significant aortic insufficiency it is usually syphilitic or rheumatic in

origin In uncomplicated arteriosclerosis it is rarely possible to demonstrate much increase in the size of the aorta except as manifested by an extension upward Under the latter circumstance an impulse may be transmitted to the palpating finger in the suprasternal notch

During the early course of angina pectoris there may be no significant cardiac findings *The diagnosis thus may be solely dependent on the clinical history and the demonstration of arteriosclerosis elsewhere*

The kidneys are rarely spared in the arteriosclerotic process The urine frequently shows a trace of albumin and on microscopic examination hyaline and occasionally granular casts are seen In some the renal damage may be more extensive and occasionally a renal insufficiency is discovered Bell and Clawson[14] place the incidence of renal insufficiency at approximately ten per cent in those with hypertension Cardiac and renal failure may appear about the same time Either may occasionally precipitate the other In men the possibility of a bladder retention from an enlarged prostate should always be considered The incidence of diabetes mellitus is much higher than that of renal insufficiency The changes in the peripheral arteries may be extensive but often not comparable to those of the cerebral and coronary arteries

Examination of the fundi is essential to a careful survey of the vascular system The findings in the retinal vessels indicate in general the extent of the cerebral arteriosclerosis and are representative of the changes in the smaller arteries elsewhere

Electrocardiographic Findings The electrocardiograph has been one of the factors responsible for the widespread interest in arteriosclerotic heart disease and has contributed in a very significant manner to a more comprehensive understanding of the subject In some instances it is true the electrocardiographic findings are not of importance in others they corroborate the clinical impression obtained by other means Finally however there is a group in which they broaden to a considerable extent our conception of the condition and thus have a decided bearing on the prognosis

The changes in the ventricular complexes as might be expected are the most important electrocardiographic signs in arteriosclerotic heart disease In general an enlarged left ventricle is associated with a left axis deviation This is more commonly seen in the advanced form in which hypertension is of considerable duration The T deflection is

frequently altered in this type of curve particularly if there is some increase in the duration of the Q R S group being a negative phase in Lead I and occasionally in Lead II [15] A negative T deflection in Leads I and II is generally regarded as indicating significant myocardial damage [16] This finding excluding the alteration induced by digitalis is of greater importance when not associated with a preponderance curve A sharp negative T-deflection in the absence of a broadening of *the Q R S group with perhaps alteration in the R T or S T interval or a* Q wave should suggest the possibility of a coronary accident [1] This diagnosis is almost certain particularly in the presence of history of pain or if there is a progressive change in the electrocardiogram

Prolongation of the Q R S group [18] as in bundle branch block and arborization block [19] is occasionally encountered These curves particularly the latter are usually associated with advanced coronary artery disease and with extensive replacement of the myocardium by fibrous tissue Various observers have unanimously agreed that they usually warrant an unfavorable prognosis

Minor changes in the Q R-S group are of less importance These are occasionally seen in Lead III of the electrocardiogram of the normal individual If however they occur in all leads and particularly if slurring appears *near the peak of the most prominent wave they are* regarded as indicating an interruption in the spread of the excitation wave within the ventricle which ordinarily results from coronary artery disease

Diagnosis *Coronary artery disease even in the advanced form* may not be recognized because of the absence of clinical manifestations In others the symptoms may be indefinite and difficult to connect with *the heart The clinical history is by all odds the most important means* of determining the functional efficiency of the heart and may permit a diagnosis as in angina pectoris or even in coronary occlusion in the *absence of definite physical findings The possibility of coronary artery* disease should be kept in mind in every individual in the arteriosclerotic age Moreover the incidence is higher than generally believed in the fourth decade *An upper abdominal discomfort may be cardiac in origin* An indefinite chest pain may mean angina pectoris A persistent bronchitis or an asthmatic like attack often represents a beginning failure of the left ventricle The *appearance of a paroxysm of auricular fibrilla*

tion and certainly the onset of a permanent fibrillation, may be the first manifestation of an impaired cardiac function A careful estimation of the condition of the cardiovascular renal system is an outstanding obligation of the physician to every individual of the artiosclerotic age who seeks medical advice regardless of the apparent nature of the illness The history of an elevated blood pressure or the presence of a hypertension should at once arouse suspicion of significant arterial changes In some the cardiac findings seem unimportant or may even be overlooked unless attention is focused on the heart by the history Muffling of the first sound at the apex and a gallop rhythm are occasionally the only findings that attract the attention of the examiner A combination of these findings however always means a serious impairment of the cardiac function In the doubtful cases the electrocardiogram is not infrequently the deciding factor in the diagnosis This question is further discussed in connection with angina pectoris and coronary occlusion

Prognosis The prognosis of a patient with coronary artery disease is dependent not only on the cardiac condition but on the associate damage of the arteries elsewhere especially those of the brain and kidneys and whether or not there is a hypertension There is always a possibility that the condition may be terminated by a cerebral accident or renal insufficiency In patients with diabetes the picture is still further complicated

The efficiency of the heart is to a certain extent determined by the size If the size is extremely large the reserve capacity is certain to be very limited In cardiac failure there is always a question as to how much may be expected from treatment The restoration of the cardiac function furthermore becomes progressively more difficult with each successive failure and the extent to which the function may be restored is gradually reduced

The prognosis of angina pectoris and coronary occlusion will be considered in the subsequent discussion of these syndromes

Treatment The arteriosclerotic form of heart disease except in those who seek medical advice because of a hypertension is seldom recognized until the onset of symptoms which are usually indicative of beginning cardiac failure The treatment in the early stage is rarely difficult Restriction in the physical activities and the administration of digitalis are ordinarily sufficient to restore the cardiac function During this stage

it is frequently possible to curtail the progression of the disease through a comprehensive survey of the cardiovascular system and of the various factors which may be contributing to the cardiac disability. Infection should be eliminated when there is justifiable reason to believe that it may be influencing the general health, provided the risk and sacrifice to the patient are not too great.

The regulation of the diet in those who are inclined to overeat and the gradual reduction in the weight of the obese represent possible means of reducing the work of the heart and perhaps controlling a hypertension. The habits of living in general should be carefully studied and regulated as far as possible to fit the disability of the patient. The protection against upper respiratory infection, rest, relaxation and sleep have a decided influence on the course of the disease. In some it may be necessary to administer a simple sedative to promote the proper relaxation and induce regular sleep. If there is an auricular fibrillation, the continued or intermittent use of digitalis may be indicated to control the cardiac rate. The excessive rate of an auricular fibrillation is often an important factor in promoting the return of the cardiac failure. Occasionally during the early stages it may be possible to abolish the absolute irregularity for periods of varying intervals by the administration of quinidine sulfate. If there is conspicuous enlargement of the heart, however, the use of quinidine is rarely justified.

The theophylline and theobromine preparations, because of their dilating action on the coronary arteries[61] may be employed to a better advantage at this stage. These drugs have been condemned by some because of their failure in certain instances of angina pectoris. It should be borne in mind, however, that this disorder with few exceptions is ordinarily associated with the more advanced sclerosis of the coronary arteries, and under these circumstances it is hardly possible for any medication of this nature to have a uniformly favorable action. Obviously there are greater possibilities in those with less extensive deficiencies of the coronary circulation, and this is in accord with clinical experience.

The treatment of the more advanced forms of cardiac failure is more difficult and often demands a far more rigid regime.[62] Success again depends on a clear conception of the condition and the factors contributing to the cardiac failure. The most satisfactory results are obtained by combining all the available means which may promote the restoration of

the cardiac function Seldom are the conditions the same in any two patients and thus the measure employed must vary with the individual possibilities

1 *Rest Relaxation and Sleep* The reduction in the cardiac load is one of the fundamental objectives in the treatment Rest relaxation and sleep are indispensable to this objective It therefore is essential that the patient with advanced cardiac failure be confined to bed at as nearly absolute rest as possible Thus it is important that the bed be comfortable and easily adjusted so that the head may be elevated to the desired level The patient should be spared all unnecessary effort in the taking of food and liquids and the use of the bed pan by careful nursing

Sleep is by all odds the most important means of resting the heart therefore it should be induced if necessary by morphine or codeine Morphine because of its favorable action under these circumstances is one of the most valuable drugs in the treatment of advanced cardiac failure It should be given in sufficient amounts to produce sound sleep and in those in whom it is possible to restore the cardiac function it is seldom necessary to continue the administration for more than two or three nights In the meantime a simple sedative as phenobarbital 0 32 Gm (1/5 grain) may be prescribed after meals and at bedtime This promotes relaxation and after a few days will enable the patient to sleep throughout the night and even some during the day Under these circumstances a certain amount of sleep should be encouraged during the day

There are frequently other means of reducing the cardiac load as the temporary reduction of the blood pressure in hypertension venesection and the removal of excess fluid from serous cavities In those with excessive hypertension the administration of nitroglycerin 0 6 mg (1/100 grain) under the tongue every two hours or even oftener may produce a striking influence on the breathing and in turn promotes relaxation and sleep The effect on the heart is twofold through the reduction of the load and the dilating action on the coronary arteries

In the plethoric cyanotic individuals particularly those with a hypertension the removal of 500 cc of blood from a vein of the arm is often followed by an immediate improvement in the condition If the peritoneal cavity contains a large quantity of fluid an abdominal paracentesis may be done following the venesection The same holds for excessive fluid in the pleural cavity Here however there is a certain risk con

nected with the procedure which should be taken into consideration. In each of these measures, the disturbance of the patient should be reduced to the minimum by the use of a sharp needle, novocain, and possibly a preliminary administration of morphine. The benefits derived are often striking and may have a decided influence on the later treatment.

2. *Diet:* The diet should be simple and meet the nutritional requirements of the body. The author employs a diet[63] consisting of 50 Gm. (1⅔ ounces) protein, 110 Gm. (3⅔ ounces) fat, and 220 Gm. (7⅓ ounces) of carbohydrates with an energy value of approximately 2100 calories. It is served in the form of milk, cream, butter, eggs, puréed vegetables and fruit, cooked cereal, and fruit juices. The carbohydrates are increased by adding various sugars, as dextrimaltose, glucose and lactose, frequently supplemented by stick candy. Small feedings are given at frequent intervals. In those with *edema,* the fluid intake is restricted to 1500 to 2000 cc. (3 or 4 pints) and the salt is reduced to the minimum. The diet is gradually increased by the addition of puréed vegetables and fruits, jellies, toast and crackers. In those greatly undernourished, it is gradually increased to approximately 3000 calories with a proportionate increase in the protein. This diet has the advantage of being easily assimilated and may be regulated to taste. Personal results indicate that it has a deciding influence on the elimination of the excess fluid and the restoration of the cardiac function in advanced failure.

Recently, Master, Jaffe and Dack[64] have concluded, from the study of 28 patients with coronary occlusion and 14 with angina pectoris, that it was possible to reduce the basal metabolic rate by the use of a low caloric diet. This consists of 80 Gm. (2⅔ ounces) carbohydrate, 50 Gm. (1⅔ ounces) protein, 30 Gm. (1 ounce) fat, giving energy value of approximately 800 calories. These observers believed that this type of diet reacted favorably on the cardiovascular system, resulting in slowing of pulse rate, lowering of blood pressure and pulse pressure, diminution of cardiac output and work of the heart. There apparently were no ill effects from the prolonged undernutrition which, in some instances, was maintained for as long as 12 months. The gradual resumption of more liberal diet often resulted in a rise of the basal metabolic rate.

The patient with cardiac failure should have a daily bowel movement. The diet briefly outlined, because of its fruit and vegetable content, will

frequently produce one or more movements during the 24 hours. Should the bowels not move daily, a simple laxative or petrolagar is advised. The removal of excess fluid by the bowel is rarely necessary. Furthermore, the violent purging incident to this form of treatment is liable to upset the function of the gastrointestinal tract and, in addition, impose unnecessary work on the heart through the frequent use of the bedpan.

3. *Digitalis:* In the foregoing discussion the various means of reducing the cardiac load were considered. The second objective in the treatment of cardiac failure concerns the use of drugs that increase the efficiency of the heart. Digitalis is, by all means, the most important drug of this group. The benefit derived from this drug is mainly through the direct action on the heart muscle and the depressing effect on the conduction system.[65]

In cardiac failure with a regular rhythm, the effect of digitalis is largely dependent on the direct action on the heart muscle which increases the length of systole and prolongs the refractory period. When there is an auricular fibrillation, however, the above action is supplemented by the specific depressing effect on the conductivity of the auriculoventricular bundle, which accounts for the greater reduction in the cardiac rate and explains the more favorable therapeutic results.

The administration of 0.9 to 1.2 cc. (15 to 20 minims) of a reliable tincture, or 0.1 to 0.13 Gm. (1½ to 2 grains) of the powdered leaf, three times a day, is ordinarily sufficient to produce the desired results. Occasionally, it may be necessary to prescribe larger doses. If, however, results are not obtained with digitalis in the above amounts, it has rarely been possible for the writer to promote recovery by increasing the dose.[70] In general, too much reliance is placed on digitalis, and the first objective, namely, the reduction in the cardiac load, is neglected. The results of the writer indicate that the heart is more susceptible to the effects of digitalis if adequate means are taken to reduce the cardiac load.

It is frequently necessary to reduce the above dose after a few days or a week. The continued or periodic use of digitalis in small doses is often advisable in the arteriosclerotic form of heart disease after recovering from cardiac failure. In those with auricular fibrillation, it is extremely important that the cardiac rate be controlled. Ordinarily, 0.6 cc. (10 minims) of the tincture, or 0.065 Gm. (1 grain) of the powdered leaf, two to three times a day, is sufficient.

4 *Theobromine and Theophylline Preparations* The use of the theobromine and theophylline preparations were mentioned in the discussion of the treatment of the earlier manifestations of coronary artery disease These preparations until recent years were employed only as diuretics They, however have through their dilating action on the coronary arteries, another very important function and are thus indicated in the treatment of all forms of coronary artery disease The results are best in those with congestive failure with extensive edema[71] Under these circumstances the heart profits from the combined action of the drug Thus, the reduction in the cardiac load resulting from the diuresis adds to the benefit derived from the increased coronary circulation Experimental studies indicate that theophylline ethylene diamine and theocine of the theophylline group have the greatest effect on the coronary circulation The former in particular is very extensively employed in the treatment of arteriosclerotic heart disease It is usually prescribed in doses of 0 1 to 0 29 Gm (1½ to 4½ grains) three times a day Theocine is more commonly used for its diuretic effect It too however may be administered in doses of 0 13 to 0 2 Gm (2 to 3 grains) for weeks without disturbing the function of the gastrointestinal tract Theobromine also has its followers and is occasionally employed in the alkaloid form More recently theobromine calcium salicylate (theocalcin) has been extensively advertised The dose recommended ranges from 0 5 to 0 65 Gm (7½ to 10 grains), three times a day It is believed that the administration of these preparations should be continued for weeks or even months in order to derive the maximum benefit

5 *Mercurial Diuretics* Salyrgan is frequently employed because of its profound diuretic effect However it is more or less toxic to the renal parenchyma and the urine must be watched for granular casts and erythrocytes Albumin alone is not a contraindication It is administered either intramuscularly or intravenously in 1 to 1 5 cc (16 to 24 minims) doses and repeated at two to three day intervals A smaller dose is frequently effective The diuretic effect is more certain and striking when the drug is combined with the administration of ammonium chloride or ammonium nitrate in doses of 1 3 to 4 Gm (20 to 60 grains) three times a day

6 *Total Thyroidectomy* In 1933 Blumgart Levine and Berlin[66] proposed total thyroidectomy in the treatment of advanced cardiac failure

Blumgart[67] and Levine,[68] and their associates have since reported further experience with this procedure and recorded favorable results In a more recent review by Blumgart[69] he concludes the operation can be performed in properly selected cases with little risk and that many months of increased comfort and activity can be added to life He points out that certain aspects of the problem still require further study *viz* to what extent is the life expectancy of the patient prolonged by the operation and should patients be operated on earlier in the downward clinical course? However during the past few years this method of treatment has seldom been employed

Acute Left Ventricular Failure, Paroxysmal Dyspnea, Cardiac Asthma This is a common clinical manifestation in coronary artery disease and in the more severe form demands prompt and energetic treatment Morphine sulfate 15 mg (¼ grain) administered subcutaneously is perhaps the most effective remedy It should be given at once and repeated if necessary Theophylline ethylenediamine when used intravenously probably ranks next to morphine in effectiveness in the treatment of this condition In the practice of the writer 0 48 Gm in 50 to 100 cc of 50 per cent dextrose solution is injected very slowly into the vein This is very useful both in preventing and abolishing attacks and in certain instances has been a lifesaving measure Improvement is usually apparent shortly after the injection is instituted Digitalis is indicated providing the individual has not already received a sufficient amount A preparation for intravenous use may be added to the theophylline ethylenediamine and the dextrose solution Venesection is advisable particularly in the plethoric type of individual The rapid withdrawal of 500 cc of blood at once reduces the venous return to the right heart and thereby decreases the pulmonary congestion If the attack continues after one or more of these measures has been employed the administration of oxygen should be instituted by nasal catheter if a tent is not available It is well to bear in mind that one should never rely on one remedy alone but combine as many as circumstances justify The subsequent treatment is the same as that outlined for advanced cardiac failure If the acute left ventricular failure is the first expression of the cardiac disability coronary occlusion is generally responsible Because of the pulmonary congestion salyrgan is a valuable remedy even in the absence of peripheral edema It is

important that the state of the lungs be checked from time to time and if the congestion returns the use of salyrgan repeated

7 *After treatment* This is an important factor in the subsequent course of the cardiac disability The return of the symptoms may be delayed for a few weeks or on the other hand may be postponed for months or possibly years The restoration of the heart to the maximum efficiency *is the ultimate aim This entails a prolonged period of rest* combined with a gradual rehabilitation of the cardiac muscle and finally the removal or control of all possible factors which may be contributing to the cardiac disability as outlined in the discussion of the treatment of the early manifestation of coronary artery disease

The exercise should be increased very gradually and never to the point of shortness of breath If the patient avoids becoming winded he may be certain that he is not placing an excess load on the heart It is well that *he understands in the beginning that he has a permanent disability within* the limits of which he must live to avoid further trouble

ANGINA PECTORIS

Angina *pectoris is one of the most characteristic manifestations of* coronary artery disease Arteriosclerosis of the coronary arteries which is usually extensive and associated with partial or even complete obstruction of certain vessels is the common pathological finding In the instances in which this process is confined for the most part to the aorta such as in syphilitic aortitis there is frequently encroachment on or an occlusion of the opening of one or both coronary arteries Keefer and Resnik[6] *in a review of the mechanism of angina pectoris considered in detail the* pathology associated with this condition They collected a series of 386 cases from the literature and added 13 of their own Sclerosis of the coronary arteries was demonstrated in 381 of the total 399 cases These authors pointed out that aortic insufficiency was the predominating lesion in the instances of angina not associated with coronary artery disease and in a vast majority of these the valve leakage was secondary to syphilitic *aortitis* The above findings are in general accord with those of other observers Exceptions are encountered in literature but one cannot always be certain regarding the diagnosis or the care with which the coronary arteries were examined

Mechanism The mechanism of angina pectoris has been discussed extensively and many explanations advanced the most favored being

aortitis, coronary artery disease, fatigue of the myocardium, and anoxemia of the cardiac musculature It is apparent that the latter two are closely related and all, with the possible exception of the first, are fundamentally dependent on an inadequate coronary circulation The fact that the occlusion of a coronary artery is followed by pain indistinguishable from that of angina pectoris except perhaps from the standpoint of intensity and that the basic pathology in the two conditions is ordinarily identical indicates that the mechanism is similar This conception is further supported by the experimental studies of Sutton and Lueth [22] in which pain was induced in a dog by the constriction of the lumen of a coronary artery Moreover, Feil and Siegel,[22] Wood and Wolferth,[23] and others have observed temporary changes in the electrocardiogram during attacks of angina similar to those of coronary occlusion

The blood supply to the various sections of the myocardium under normal conditions is undoubtedly ample to meet the needs even during periods of stress If this is diminished to a certain area the efficiency of that section is reduced Thus, this area of the myocardium may be over taxed by a load that is well within the functional capacity of the remaining cardiac musculature While it is well known that the occlusion of a coronary artery may produce severe pain it is conceivable that a less extensive disturbance of the blood supply to the same area of the myo cardium may, during periods of exertion cause distress with the same fundamental characteristics, but less severe, and disappear soon after the excessive exertion is discontinued Therefore, it would seem that angina pectoris and coronary occlusion differ only in the extent to which the function of the myocardium is disturbed

Angina pectoris is occasionally observed in the rheumatic type of aortic insufficiency,[20] arteriovenous aneurysm,[24] paroxysmal tachy cardia [25] high grade anemia [26 27 28] hyperthyroidism [29] and hypothyroidism [29 30] Upon analyzing these conditions it is apparent that there are one or more factors which may reasonably promote the produc tion of angina In aortic insufficiency the demands on the heart are increased by the valvular leakage Moreover, the cardiac efficiency is diminished by the reduction in the diastolic blood pressure Experi mental studies have demonstrated that the diastolic blood pressure is one of the most important factors in maintaining the coronary circulation [31] If this is diminished there is at once a significant reduction in the coronary

circulation, even though the systolic pressure remains constant or is even slightly elevated. In the experiments by the author the increase in the systolic pressure never compensated for the effects produced by the alteration in the diastolic pressure

It is generally known that there is an increase in the size of the heart and that cardiac failure may occur in arteriovenous aneurysm The correction of this condition by operation has in certain instances been followed by reduction in the size of the heart even after the development of the clinical manifestations of cardiac failure [11] Here again the change in the diastolic pressure incident to the development of the arteriovenous aneurysm is unquestionably a factor in the production of the cardiac disability

Studies on the physiology of the coronary circulation have also contributed to the explanation of angina during paroxysmal tachycardia [12] *Experimentally produced tachycardia is associated with striking reduction* in blood pressure which is in accord with certain clinical observations Furthermore, the excessive cardiac rate increases the demand on the heart In high grade anemia the reduced oxygen-carrying power of the blood produces the same end result in a different manner The hypermetabolism in thyrotoxicosis obviously adds to the work of the heart Furthermore, it has been shown that the heart shares in the general *increased metabolic rate These factors are present even while at rest* and certain observations indicate that they are disproportionally increased during exercise or excitement Fatigibility is an outstanding clinical manifestation in hypothyroidism Moreover, changes occur in the myocardium, particularly in the more advanced form, which undoubtedly react adversely on the cardiac efficiency

In the above conditions various factors add to the demand on the heart or render this organ less efficient Consequently, angina is more easily precipitated than under normal circumstances Since these disorders are amenable to treatment, it is often possible to eliminate the angina as illustrated by the following patient

A man 58 years of age consulted the writer because of pain in the chest extending to the left shoulder and arm and precipitated by exertion or excitement These attacks had persisted despite a period of several months' rest It became apparent particularly after a detailed history and conversation with the patient's wife that this man was on edge and

easily upset. There was no demonstrable increase in the size of the thyroid gland but further study disclosed elevation of the metabolic rate. A subtotal thyroidectomy was advised following which the anginal attacks disappeared. This patient had no further trouble until four years later when he returned to the hospital because of nocturnal dyspnea.

In this patient, as in the vast majority of those of the miscellaneous group under observation, arteriosclerosis is basically responsible for the angina. Thus the development of these various conditions merely served as precipitating factors.

Finally, the state of the autonomic nervous system has a significant influence on the occurrence and intensity of anginal attacks. Other conditions being equal, those with overresponse to normal stimuli are more susceptible to pain. This unquestionably is a factor in those with thyrotoxicosis and in the hypersensitive types of individuals and has an important bearing on the treatment.

Within recent years the opinion that an inadequate coronary circulation is primarily responsible for angina pectoris in the vast majority of cases has become the prevailing conception. The exact mechanism by which the pain is produced, however, is largely a matter of speculation. Those interested in this question would profit greatly by the reading of Lewis' article.[33] In this connection it is well to bear in mind that prior to the identification of the syndrome of coronary occlusion the latter was included in the description of angina pectoris. A survey of the older literature on this condition discloses many instances of coronary occlusion. The book by Sir James Mackenzie is one of the more recent examples. The essential unity of these conditions as regards the pathological state of the coronary vessels is deserving of particular emphasis. Angina commonly developes following the recognized occlusion of one of the larger coronary arteries. It likewise undoubtedly may follow the closure of smaller branches. In fact, despite the character of the onset, the possibility of coronary thrombosis should be suspected. This conception, as pointed out by Parkinson[34] is important from the standpoint of treatment, for if the situation is recognized and the proper management is instituted, it is possible that the angina may be prevented or postponed.

Symptoms. The typical form of angina pectoris is generally known. The clinical manifestations, however, are variable and may be confused with other conditions or even be overlooked. In the beginning there

may be no more than a mild uneasiness or an indefinite sense of discom fort in the substernal region a history of which may be elicited only by carefully questioning the patient While the pain is usually regarded as being substernal and felt near the level of the third rib it may be at a higher or lower level In typical cases the pain is transmitted to the left shoulder and often down the arm on the ulnar side to the elbow and *frequently to the fingers Occasionally the* distress is transmitted to the right shoulder and down the arm In some patients the discomfort is first felt in the arm and later if the exciting factor is continued appears in the usual location in the chest The pain in some cases may radiate to the head and neck and be felt in pharynx jaw mastoid region or the ear *without appearing in the arms or it may begin in the neck or head and* later reach the chest The distress is not infrequently over the lower chest and upper abdomen and occasionally may be entirely confined to the abdomen

In certain instances pain may be limited to some peripheral point as *the throat jaw shoulder or the arm Cases are recorded in the litera ture*[3] in which special throat examinations were made because of the distress in this location teeth extracted because of pain in the jaw and the shoulder treated for an arthritis The writer has recently had under observation a patient in whom the pain was confined to the left side of the neck and shoulder This patient had been treated for arthritis of the left shoulder The history revealed definite relation between the pain and effort or other factors which increased the demands on the heart Moreover the pain was relieved by nitroglycerin

Even though the *distress may vary in character and have a wide* range of distribution the type of pain except for the degree of intensity and the extent of radiation during different attacks in the same individual is constant Furthermore the attacks of pain except perhaps in the very severe form where there is always a question of coronary occlusion are *usually excited by factors which increase the work of the heart* The exciting factor may be the added effort of walking or climbing stairs or it may be the load imposed on the heart by the increase of the blood pressure accompanying excitement or again the interference with the cardiac function from *overdistention of the stomach by a full meal* or possibly the associated accumulation of gas In some instances the patient is awakened from sleep by pain It is possible that some of these may be

induced by the increase in blood pressure resulting from sleep disturbances There is however always the possibility of coronary occlusion

Findings The cardiac findings in angina pectoris are variable or may be entirely negative In those with demonstrable structural changes in the heart the findings are those previously outlined under the general discussion of *coronary artery disease* An x ray examination and Wassermann test are indicated in every instance where the possibility of syphilis is suspected

The electrocardiogram may be helpful in the cases in which it is not possible to demonstrate structural changes by other means In certain instances there are no *significant* alterations in the electrocardiogram Some of these however may show changes in the T wave the R T and S T intervals following exercise Others present persistent alterations indistinguishable from those observed following coronary occlusion In a patient studied by the writer in whom there was some question regarding the history *a conspicuous Q wave in Lead III was the only finding* suggestive of coronary disease The subsequent course was quite characteristic of angina pectoris This patient later had coronary occlusion and finally died from cardiac failure The necropsy disclosed extensive sclerosis of the coronary arteries with complete obstruction of the anterior descending branch of the left coronary artery and a healed infarct involving the anterior apical region of the left ventricle and the interventricular septum

Diagnosis Angina pectoris in the typical form is readily recognized In those with an unusual distribution of the pain the diagnosis may be *difficult When the distress is confined to the epigastrium and lower chest* and particularly when associated with an accumulation of gas the condition is frequently mistaken for a *gastric disorder* or *gallbladder disease* Not infrequently the early manifestations of angina may appear to be entirely gastric and their significance not appreciated *until later developments* It is always well to bear in mind the possibility of angina pectoris in every individual in the arteriosclerotic age who has a vague epigastric distress Ordinarily a careful detailed history and a critical survey of the cardiovascular system will enable the physician to come to a fairly definite conclusion regarding the possibility of angina In the atypical form the history is by all odds the most important step in the diagnosis and often

the determining factor. This point is illustrated by the following case, which has previously been cited.[37]

A man past 60 years of age consulted the writer because of a distress which was definitely localized in the epigastrium. This distress was described as a feeling of heaviness, which appeared at fairly regular intervals, especially after the midday meal. Because of the location and the periodicity of the distress, a diagnosis of peptic ulcer had been made. Upon questioning the patient, it was discovered that the discomfort was seldom experienced except after lunch. It was further found that the patient was in the habit of walking to his office about one hour after lunch, and it was during this time that the distress was usually noticed. He had observed that the pain promptly subsided after reaching his office and that he might obtain relief by resting on the way.

The precordial or upper chest pain from an *intercostal neuralgia* or the nerve-root pressure from a *mediastinal tumor, tuberculosis of the vertebra,* or *a hypertrophic osteoarthritis of the spine* may, at times, arouse suspicion or even closely resemble that of angina pectoris. Usually, the history is different and the physical examination will point to other possibilities.

Coronary occlusion has frequently been mistaken for the severe form of angina pectoris. The character and distribution of the pain may be identical. The pain in coronary occlusion, however, is usually more lasting, and, instead of disappearing in a few minutes, may continue for hours or days and may be present in minor form even after repeated hypodermic administration of morphine. The onset is frequently accompanied by shortness of breath and may be followed by the other signs of cardiac failure, particularly cyanosis and coughing. The changes in the cardiac findings may be sufficient to permit a definite diagnosis, even where the history is atypical. The distant and indistinct cardiac tones, gallop rhythm and premature contractions at once attract attention to the heart. The later appearance of a systolic apical murmur and the occasional pericardial friction rub on the following day are conclusive evidence of cardiac damage. These, along with slight elevation in temperature, moderate leukocytosis, and reduction in blood pressure, in the main, complete the clinical picture. If electrocardiograms are taken daily, the curves will often show alterations in the ventricular complexes, with progressive changes in the R-S-T segments and the T deflection.

The differentiation of angina pectoris from the minor forms of coronary occlusion is extremely difficult yet very important from the standpoint of treatment In every instance in which the attack of angina is more severe than usual or comes on while at rest the possibility of coronary occlusion should be considered and when in doubt the patient given the benefit of a period of absolute rest If in questionable cases the heart is carefully watched for possible changes in the findings the clinician will occasionally be rewarded by detecting a gallop rhythm or a pericardial rub the latter of which definitely establishes the diagnosis The electrocardiogram renders the greatest service in these atypical cases The changes however may be easily overlooked unless progress curves are taken

Prognosis The future of a patient with angina pectoris is always in doubt because of the possibility of sudden death It is well to bear in mind however as pointed out by Herrick[36] that recovery occurs improvement is common and some have been known to live 20 years The literature of recent years has expressed a more optimistic attitude toward the prognosis in angina pectoris In the series of 500 cases studied by White and Bland[38] the average duration of symptoms was 4 4 years in the 213 known to be dead and 5 1 years in the 273 still living The report by Wedd and Smith[39] is of particular interest In a series of 166 cases the average duration of the disease was 5 8 years and the average age at death was 64 3 years It was pointed out that 26 (15 7 per cent) lived ten years or longer Moreover 70 per cent reached or exceeded the calculated life expectancy and 48 per cent passed it by five or more years Hart[40] has also emphasized the favorable aspect of this problem citing instances from his own experience and referring to his analysis of the case histories published by Sir James Mackenzie In 147 cases classified by Mackenzie as primarily angina one man was still living 31 years after his first attack three had lived 20 years seven lived 15 years or more and 21 lived ten years or more Thus of the 147 cases 33 had lived more than ten years after the onset of the disorder and 16 were still living at the time the book was published It is not possible however to calculate with any degree of certainty the outlook in angina pectoris This can be determined to a certain extent by the general condition of the cardiovascular system the size of the heart and the frequency and severity of the attacks The prognosis is obviously poor in those with advanced changes in the

cardiovascular system and the gravity of the situation is still further increased by the frequent occurrence of severe attacks The progress in those with luetic aortitis is usually *progressively downward*

In general the prognosis is most favorable in those with normal blood pressure and in whom it is not possible to demonstrate significant structural changes in the heart

The angina associated with hypothyroidism hyperthyroidism high grade anemia etc may frequently be eliminated by the treatment of these conditions The general temperament of the patient should be taken into consideration In those with a hypersensitive nervous system the basic pathology necessary to the production of the pain may be considerably less than in the placid individual This is a recognized factor in the angina of women and probably contributes to the production of the syndrome in hyperthyroidism Finally those patients who are faithful in complying with the recommendation of the physician may add years to their life whereas on the other hand they may precipitate a sudden termination by the disregard of factors which excite the pain

Treatment It is generally possible to benefit the individual with angina pectoris and oftentimes a great deal may be done The extent to which this may be accomplished however depends in a large measure on the care with which the physician analyzes the patient the condition of the cardiovascular system and all factors pertaining to the precipitation of attacks and adopts measures to correct or alter the situation In general the objective in treatment of this form of cardiac failure is the same as that previously outlined Here again rest is one of the most effective means of restoring the cardiac function However it is not usually necessary to confine the subject to bed

In the milder form curtailment in the exercise alone may produce marked improvement Thus a reduction in the physical activities to a point where pain is not produced is the first step in the treatment A period of rest with complete relaxation and perhaps additional sleep is often advisable Phenobarbital 30 mg (¼ grain) three or four times a day or some other form of mild sedative is often helpful or even essential to the promotion of relaxation and the induction of adequate sleep The diet should be simple and overeating avoided Excessive accumulation of gas is not infrequently a disturbing factor and often associated with constipation Thus the bowel function should be controlled by as simple

a measure as possible in order to reduce irritation to the minimum In the obese a gradual reduction in weight is indicated This commonly has a favorable influence on an associated hypertension If the blood pressure of those with hypertension is not sufficiently reduced by rest relaxation and the curtailment in the weight of the obese the administration of nitrites is justified in order to temporarily reduce the work of the heart Moreover this medication in addition will have a favorable influence on the coronary circulation These preparations particularly amyl nitrite and nitroglycerin are not ordinarily employed except for the relief of pain The regular administration of those with more persistent action however is justified in the hope of improving the coronary circulation and thus perhaps eliminate the underlying cause of the angina

There are instances in which such factors as infection enlarged prostate diabetes anemia thyrotoxicosis hypothyroidism etc may be contributing to the development of the angina The various possibilities should be carefully weighed and judicious treatment employed The rigid control of the diabetes however is not justified and when insulin is employed hypoglycemia should be avoided It is well established that the angina may be aggravated under these circumstances Moreover in hypothyroidism it is important that caution be exercised in the use of thyroid medication otherwise the increased demands on the heart imposed by the elevation of the metabolic rate may overweigh the beneficial effects from abolishing the hypothyroid state

The various theophylline and theobromine preparations have their place in the treatment of angina pectoris As previously pointed out however their possibilities are not as great in this form of heart disease because of the extent of the deficiency of the coronary circulation usually present Nevertheless they should be given a chance in combination with the various other measures and favorable results have been reported [72] The writer has employed theophylline ethylenediamine for years and is convinced of its value The usual dosage is 0 1 to 0 2 Gm (1½ to 3 grains) three to four times a day Others favor the use of theobromine preparations such as the alkaloid theobromine 0 3 to 0 5 Gm (5 to 7½ grains) theobromine calcium salicylate 0 5 Gm (7½ grains) or theobromine sodium acetate 0 6 Gm (10 grains) three times a day All of these purine base derivatives may cause gastric irritation but in the

experience of the writer this has not been an objectionable feature with theophylline ethylenediamine

Nitroglycerin, 0 65 mg ($1/100$ grain), frequently gives prompt relief from an attack It should always be available and taken at once at the onset of pain and repeated if necessary Occasionally unpleasant, and in rare instances ill effects are observed Therefore, the drug should not be prescribed until its action is determined In certain instances the writer has combined the use of nitroglycerin and theophylline ethylenediamine with favorable results

In the more severe form of angina pectoris the treatment is much the same as in the advanced stage of congestive failure Every available means should be employed to reduce the work of the heart and improve the *efficiency of the myocardium A prolonged period of rest relaxation and* sleep may be necessary Sedatives are usually indicated and morphine often necessary to promote relaxation and sleep and thus obtain the *maximum mental and physical rest The administration of digitalis in* doses of 0 6 to 0 9 cc (10 to 15 minims) of the tincture, or 0 06 to 0 1 Gm (1 to $1\frac{1}{2}$ grains) of the powdered leaf is frequently indicated *Nitroglycerin may be an extremely valuable remedy in this stage of the* disease After the patient is allowed to leave the bed there is a greater necessity for a more detailed supervision of the exercise and other factors *which induce the pain*

Surgical Treatment Sections of various portions of the sympathetic chain and later paravertebral injection with alcohol have been employed in the treatment of angina pectoris The latter is by far the simplest procedure and to date the results have been successful in a high per centage of cases This method of treatment is usually reserved for those with a more severe form of angina who are not able to get relief by med ical measures Moreover, it should not be attempted except by one who has expert anatomical knowledge and experience Total thyroidectomy has been advocated for the treatment of the more refractory cases on the basis that the resulting hypothyroidism might sufficiently reduce the work of the heart to permit the restoration of cardiac function but is now seldom used More recently Beck *and others have attempted to improve* the circulation to the heart by the production of extracardiac anastomosis This work is still in the experimental stage

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There are instances in which such factors as infection, enlarged prostate, diabetes, anemia, thyrotoxicosis, hypothyroidism, etc., may be contributing to the development of the angina. The various possibilities should be carefully weighed and judicious treatment employed. The rigid control of the diabetes, however, is not justified, and when insulin is employed hypoglycemia should be avoided. It is well-established that the angina may be aggravated under these circumstances. Moreover, in hypothyroidism *it is important that caution be exercised in the use of thyroid* medication, otherwise the increased demands on the heart imposed by the elevation of the metabolic rate may overweigh the beneficial effects from abolishing the hypothyroid state.

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CORONARY OCCLUSION

The recognition of the clinical syndrome of coronary occlusion introduced a new chapter in the knowledge of coronary artery disease. It furthermore stimulated a widespread interest in the subject which led to an extensive investigation of the anatomy[1-3, 4, 41] physiology and pathology[32, 33, 42, 43, 44] of the coronary arteries,[10, 12, 45] experimental and clinical electrocardiographic studies[17, 46] and finally a careful clinical survey of the various aspects of coronary artery disease.[8, 9, 10, 12, 47] While the syndrome was first definitely identified by Obrastzow and Straschesko[48] in 1910, the report by Herrick[49] in 1912 and his later publication[50] on the subject stand out as a milestone in the subsequent developments in this new field of medicine.

The essential features in the pathology of coronary occlusion have been discussed. It should be remembered, however, that coronary occlusion usually represents a terminal manifestation of coronary artery sclerosis. The atheromatous changes in the coronary arteries are comparable to those ordinarily associated with angina pectoris. In this connection the findings of Klotz and Lloyd[51] are of particular interest. These investigators made a comparative study of the clinical and pathological findings in a series of 26 cases of advanced coronary artery sclerosis and a series of 18 cases of coronary occlusion. They concluded that there was no significant difference between these series either in the clinical manifestations or the post mortem findings. It is interesting to note that the incidence of angina pectoris was practically the same in both groups.

Coronary occlusion may occur with only moderate sclerosis and perhaps confined for the most part to the vessel obstructed. Generally, however, the sclerotic process is quite marked, usually involving both the *right and left coronary arteries, and frequently more than one complete* occlusion is found at necropsy. The latter is commonly the situation in cases of sudden death. This type of death was recorded in 1[illegible] of the 34 cases studied by Saphir, Priest, Hamburger and Katz[52] and in every instance there was an old as well as a recent occlusion. These observers expressed the belief that the closure of a single main branch is not sufficient to cause instantaneous death.

The opinion advanced by Leary[53] from the study of the development of the arteriosclerotic lesions of the coronary arteries, especially the events leading to the closure of a vessel, is of particular interest. He concludes

that these lesions arise from the entrance of lipoids into the subendothelial layer of the intima and their phagocytosis by cells referred to as lipoid cells. In the young, the lipoid cells stimulate the growth of fibrous tissue which encroaches on the lumen and may terminate in thrombosis. In the old, however, the lipoid cells do not stimulate fibrosis but, because of the accumulation in large masses and of inadequate nutrition, undergo necrosis and autolysis, forming atheromatous cysts or abscesses. The occlusion of the vessel, under these circumstances, is usually due to the rupture of an abcess into the lumen.

The immediate response of the heart to the occlusion of a coronary artery depends on several factors such as the previous state of the coronary circulation, size of the vessel obstructed, and whether the closure is sudden or abrupt. Many withstand the thrombosis of one of the larger vessels without any particular embarrassment of the heart. In others there is obvious impairment in the cardiac function. Finally, there are those in whom the effect is so overwhelming that sudden death or extreme cardiac failure results. Despite a favorable condition at the onset, however, the subsequent course is always in doubt. There is always the possibility of the extension of the infarct or perhaps the development of a new one. Moreover, if the infarct involves the endocardium to a significant extent, mural thrombi will commonly develop. These often involve both the right and the left ventricles, and there is always a chance that some may be dislodged and pass into the circulation. Blumer[53a] in reviewing this subject states that about 50 per cent of the patients with cardiac infarction present mural thrombi and in approximately 14 per cent embolic manifestations occur. He points out that the embolus is more likely to take place during the first ten days and more frequently involves the lungs. In the series of cases cited other structures such as the kidneys, spleen, extremities, and brain were concerned in the order mentioned.

Occasionally an area of softening involving the entire thickness of the wall of the left ventricle permits rupture and hemorrhage into the pericardial sac resulting in death from cardiac compression. The rupture is usually located on either the anterior or posterior wall of the left ventricle. In rare instances the interventricular septum is involved in this manner from the occlusion of the anterior descending branch of the left coronary artery. This is manifested by the appearance of a systolic

murmur over the precordium, which is most intense in the left parasternal region in the fourth and fifth interspaces This murmur may be high in pitch or even rasping in character

In those with extensive myocardial damage and as the result of wide spread replacement of the muscle by fibrous tissue the wall of the left ventricle may bulge, producing cardiac aneurysm This condition is most commonly located on the anterior apical region of the left ventricle, ordinarily a late development and usually associated with cardiac failure

Symptoms. The clinical manifestations of coronary occlusion in the typical form are readily recognized The distribution, character and duration of the pain, the accompanying shock and fall in blood pressure, the symptoms and signs of cardiac damage, and the later development of temperature and leukocytosis produce a distinctive clinical picture There is, however, a wide variation in the clinical manifestations which depends in a large measure on the extent of the myocardial damage The damage to the heart may thus be so overwhelming that the patient dies *suddenly or within a few hours, or, on the other hand, so slight that few* or no symptoms are produced and the condition possibly not recognized Again in those instances in which the pain and accompanying shock predominate the clinical picture, the associated symptoms and signs of cardiac damage may vary to a remarkable extent In some, there may be no significant dyspnea and no demonstrable structural change in the heart except as demonstrated by the electrocardiograph

There is a small group, perhaps larger than heretofore suspected, in which the onset is manifested by intense dyspnea with little or no pain Finally, in certain instances the obstruction of one of the main branches may occur without the production of significant symptoms The possibility of coronary occlusion should thus be borne in mind when an apparently unexplained cardiac failure appears in an individual of the arteriosclerotic age, particularly if it develops rather rapidly

Pain is the outstanding and most characteristic symptom of coronary occlusion Many give a previous history of chest pain which, in some instances, is typical of angina pectoris Occasionally, the distress is over the lower chest and upper abdomen and mistaken for a gastric disturbance or gallbladder disease In another group, the occlusion is the first evidence of coronary artery disease The onset of the pain may be abrupt or gradual, extending over a period of two or three days before

reaching the severe form During the period of gradual onset, the distress is usually intensified by exercise, excitement or other factors which increase the work of the heart In those with an abrupt onset, the patient is not infrequently awakened from sleep during the night and often during the early hours of the morning by the terrific distress

The site of the pain is similar to that in angina pectoris, except perhaps for a greater tendency towards the lower sternum and upper abdomen In an occasional instance, as in angina, the distress may be entirely *confined to the abdomen* *Usually the pain has a greater area of distribution* and extends laterally in each direction from the sternum It is frequently transmitted to the left shoulder and down the arm and often to both arms Whereas in those with a previous history of angina pectoris, the pain may have extended to the left arm, it will frequently be felt in both arms after an occlusion

The pain may likewise be felt in neck and various locations about the head, and, in rare instances, transmitted through the chest to the angle of *the left scapula* *The distress, particularly in those with gradual onset or* in the milder form, is often described as a mild feeling of oppression or heaviness of the chest On the other hand, it may be the most agonizing tearing boring, or constricting like pain While there is usually a steady distress the intense manifestations often come and go in wave like fashion The duration in the more severe type varies from a few hours to days and may persist, in a minor form, even after repeated hypodermic administrations of morphine While the above type of pain often follows the occlusion of a larger vessel instances of even fairly large cardiac infarction are frequently encountered at necropsy which were not manifested by significant symptoms The pain if present, must have been of a very mild nature or, in those with angina pectoris, perhaps no more than experienced during an ordinary attack Again, the clinical picture may *be so dominated by dyspnea that the pain is overlooked*

The onset of severe pain is ordinarily accompanied by profound *shock* in which the ashen gray color, the profuse perspiration, the feeble and even imperceptible pulse, and the fall in blood pressure are the conspicuous features The normal color usually returns and the perspiration disappears after the severe pain subsides The exhaustion and the feeble pulse, however, may continue for days, depending on the extent of the functional disturbance of the myocardium The systolic blood pressure

may recede to 90 mm *Hg* or even lower In those with an unrecognized hypertension the degree of the reduction in the blood pressure is likely not to be appreciated Following the occlusion of a smaller vessel the changes in the blood pressure are probably slight and transient in nature Ordinarily however after the closure of a larger artery it rises slowly but may remain at a level considerably below the original

The extent of the *dyspnea* represents a measure of the response of the myocardium to the infarction Pain and dyspnea are thus not necessarily present to the same degree Even in those with severe pain there may be no appreciable shortness of breath If however cardiac failure later develops the respiratory distress gradually assumes a prominent aspect in the clinical picture It is to be recalled however that there are instances in which the dyspnea at the onset dominates the picture and the pain is slight or possibly absent In these it is assumed that there is extensive functional disturbance of the myocardium

1 *Physical Findings* There is a great variation in the physical findings of coronary occlusion Some give a history of hypertension and have the customary changes in the cardiovascular system Again the findings prior to the accident may be surprisingly negative During and even after severe attacks of pain there may be very little alteration in the cardiac findings The character of the pulse and the fall in blood pressure have been mentioned There is usually some acceleration in the cardiac rate but rarely above 100 per minute An irregularity from premature contractions is often noted The character of the cardiac tones is perhaps one of the most constant features The tones are frequently distant and poorly differentiated This with a gallop rhythm may be the only demonstrable physical evidence of cardiac damage The occasional associated emphysema may account for the distant sounds in some instances A systolic murmur may be heard or appear later This murmur in the beginning is often very faint but later frequently becomes more conspicuous There may be no appreciable increase in the size of the heart with the above findings In those with more extensive damage of the myocardium the cardiac signs are usually more prominent with perhaps the additional manifestations of pulmonary edema and engorgement of liver

A pericardial friction rub is occasionally demonstrated It is the only distinctive physical sign of cardiac infarction The other findings are

common to the arteriosclerotic form of heart disease without demonstrable occlusion A diligent search for a pericardial rub is thus warranted in every instance in which a coronary occlusion is suspected It is usually heard on the second to fourth day frequently between the apex and sternum occasionally higher It may be soft and transient in character and ordinarily disappears after one or two days

2 *Temperature and Leukocyte Count* The temperature and leukocytosis are of considerable importance They are apparently solely dependent on the extent of the myocardial infarction The temperature is usually not noted until the second day and ordinarily reaches the highest peak on the third day after which it gradually subsides In occasional instances it may persist for a week or even longer The usual range is between 37 2 and 38 9° C (99 and 102° F)

An increase in the leukocytes has been observed as early as one to two hours after the onset of the clinical manifestations of occlusion In general it parallels the temperature and ranges from 10 000 to 20 000 per cmm These two findings have been helpful in estimating the extent of the myocardial infarction The physician is more justified in being extremely cautious and guarded in his prognosis in the presence of a brisk leukocyte and temperature reaction particularly if they persist longer than usual

According to recent observers[34] the sedimentation rate of the red blood cells is significantly altered by cardiac infarction In 29 cases studied by Shookhoff Douglas and Rabinowitz[35] the sedimentation rate was abnormally high in all This is usually evident between the second and fourth day after the cardiac accident increasing to the level of 60 mm or more and occasionally as high as 100 mm within an hour It ordinarily reaches the maximum two or three days later thereafter gradually subsiding but occasionally requiring weeks to recede to the normal level It has been pointed out that this finding may be of value in determining the rate of the healing of the infarct and thus possibly provide another means of estimating the duration of bed rest

3 *Electrocardiographic Findings* It is generally known that the changes in the electrocardiogram are frequently characteristic and may be the only means of demonstrating acute myocardial damage As pointed out by Wilson[?] however it is usually unwise to make a diagnosis on the basis of the electrocardiogram alone Thus the evidence obtained

by this method of examination should always be carefully weighed with that of the clinical findings

The electrocardiogram is continually changing during the early stages of coronary thrombosis and the alterations are commonly more conspicuous at this time therefore, serial curves should be taken at one to two days intervals or perhaps oftener in certain cases otherwise, changes may escape detection Furthermore it should be borne in mind that the alterations vary to a remarkable extent in magnitude and while usually evident in standard leads are generally more apparent when supplemented by precordial leads For the more recent recommendations regarding the use of the precordial leads the reader is referred to the joint report of the American Heart Association and the Cardiac Association of Great Britain and Ireland [55b]

The more significant abnormalities pertain to the R and S T segments the T wave and the appearance of Q wave In general there are two types of curves The first of these is usually associated with thrombosis of the anterior descending branch of the left coronary artery resulting in infarction of the anterior lateral surface and apical region of the left ventricle Soon after the accident the R T segment is elevated in Lead I and the opposite effect is noted in Lead III This is gradually replaced by sharp negative T wave in Lead I and upright deflection of the same general character in Lead III producing the T_1 type curve In certain instances significant alterations do not appear in the R S T segment and that in the T deflection is the outstanding feature When the infarction involves the posterior wall of the left ventricle the reverse order is commonly observed Thus there is downward displacement of the segment in Lead I and upright deviation in Lead III which is replaced shortly by positive T wave in Lead I and negative T wave in Lead III T_3 type of curve Within recent years the appearance of Q wave has been emphasized This wave is usually more prominent in Lead III However Wilson and his associates[55c] have shown that the leads in which the Q wave appears follow closely the order of T changes and thus designated the two types of curves as $Q_1 T_1$ and $Q_3 T_3$ The above changes in R S T segment and T wave undergo daily alterations That involving this segment is not infrequently absent or quite transient whereas the alteration in T may disappear, but commonly never returns to normal The Q wave is the more persistent.

Alterations of less significant character frequently occur The various types of irregularities have been mentioned Of these, premature contractions generally of ventricular origin are the most common and occasionally, ventricular tachycardia develops Auricular fibrillation or auricular flutter may likewise appear Conduction defects involving the auriculoventricular bundle or branches are fairly frequently observed The latter gives rise to great variety of alterations in the initial ventricular complexes such as slurring and splintering which is frequently associated with increase in duration of the Q R S group It is well to bear in mind that the occurrence of bundle branch block may mask the changes usually noted in R S T segments and the T wave Finally in certain instances there is conspicuous reduction in the amplitude of the chief ventricular deflection which may be transient or permanent

Diagnosis The typical case of *coronary occlusion is seldom over*looked by those familiar with the syndrome Difficulty usually arises because of an unusual distribution of pain Here as in angina pectoris the pain at some peripheral point may for a time at least overshadow that of the chest When however the pain is confined to the epigastrium or extends to this region particularly when accompanied by tenderness rigidity nausea and vomiting the diagnosis may be extremely difficult Patients of this age may have perforating peptic ulcer gallbladder disease or acute pancreatitis The history is extremely important It may *point to a peptic ulcer or gallbladder disease or on the other hand indicate a previous angina pectoris* I have *recently observed* a patient in whom the initial symptom was severe pain confined to the epigastrium and followed by nausea After about 30 minutes he vomited profusely and had a copious watery bowel movement following which the pain subsided Occasionally the onset is with intense dyspnea and shock Others have mentioned the combination of dizziness and shock Whenever there is rapid development of cardiac disability especially in individuals of the arteriosclerotic age the possibility of coronary occlusion should be considered Moreover the incidence of coronary artery disease in subjects below 40 years of age is higher than generally considered A *careful survey of the heart will, in most* instances, prevent the physician from overlooking coronary occlusion In doubtful cases the electrocardiogram usually establishes the diagnosis It is extremely important however, that curves be taken as soon as possible

and at one to two day intervals especially during the first week or ten days following the cardiac accident Otherwise significant alterations may be overlooked

Differential Diagnosis Various conditions in the chest such as *pulmonary embolus, acute pneumothorax,* and *massive collapse,* may be mistaken for coronary occlusion Averbuck[56] has recently reported six cases of pulmonary embolism in which the clinical diagnosis was coronary occlusion *Dissecting aneurysm* and *rupture of the aorta* may likewise be indistinguishable from acute cardiac infarction [57] Finally *pericarditis* from causes other than myocardial infarction, because of the location and character of the pain and the presence of a friction rub may closely resemble coronary occlusion The possible occurrence of electrocardio graphic changes may further add to the difficulties In fact, as indicated by Herrick,[58] only a careful analysis and watchful waiting will decide the diagnosis in certain cases

Within recent years coronary occlusion has become a common diagnosis Because of the widespread interest in this condition the time has come when there is a danger of making this diagnosis at the expense of common disorders in the upper abdomen or chest

The differentiation of *angina pectoris* and coronary occlusion was dis cussed in connection with the former condition It is well to bear in mind however that a coronary occlusion frequently precipitates and often terminates an angina pectoris It is believed that minor coronary accidents are common during the course of angina and at present, gen erally overlooked These patients should be examined with this possi bility in mind whenever the pain differs in any essential respect from that of the usual attack and particularly if it occurs while at rest It is possible that a more detailed study of the physical findings blood pressure leukocyte count and frequent electrocardiographic observations may enable the physician to recognize the minor forms of coronary occlusion much more often than in the past and alter the conception of certain instances of angina

CORONARY THROMBOSIS

Prognosis The occlusion of one of the main branches of the coronary arteries is always a serious matter and it is never possible to predict with certainty the outcome The subject may have withstood the immediate effects in a very satisfactory manner and yet succumb a few

days later from the extension of the infarct, perforation of the cardiac wall with hemorrhage into the pericardial sac or perhaps from cerebral or pulmonary embolus Numerous instances of survival, however are encountered in every large series of coronary artery disease and many have recovered to the extent that they have an efficient heart The history of many of the writer s cases indicated that they withstood the occlusion and were later free from symptoms even though they may have been permitted to be up and about the next day or at least within a few days following the attack *One patient had the clinical manifestations of an* extensive cardiac infarction at the age of 50 After a brief period of rest he apparently made complete recovery and was able to engage actively in farm work for five years without any evidence of impairment in the cardiac function At this time he had the second coronary occlusion followed by progressive congestive failure and fatal termination At necropsy an old infarct was found involving the anterior apical portion of the left ventricle and resulting from the occlusion of the anterior descending branch of the left coronary artery The more recent obstruction concerned the right coronary artery

In a series of 286 cases reported by Conner and Holt [59] the immediate mortality was 16 2 per cent *Of the* 117 cases who survived satisfactorily from the first attack 75 per cent were in good health at the end of two years 21 per cent at five years and 3.4 per cent at ten years It was interesting *to note that in 62 per cent the coronary occlusion was the first* intimation of cardiac disease In a series of 200 cases reported by White and Bland 101 were known to be dead and 91 were still alive The average duration of life in the former following the attack was 1 5 years and in the latter 3 2 years There is every reason to believe that certain of the latter may live for many more years Recurrences are common In a series of cases reported by Connor and Holt 69 patients (24 per cent) had two attacks 12 (4 per cent) had three attacks and 14 (5 per cent) had more than three attacks *Of the 370 cases recorded by Willius* [60] 297 (80 per cent) had had a single attack 73 (20 per cent) had two or more attacks The average interval between attacks being 2 2 years

In general, the course is more favorable in those in whom the heart withstands the accident without signs of cardiac failure whereas the outlook is grave in those with signs of extensive impairment of the cardiac *function during the initial stages of the occlusion* Even though the initial

period is survived, the later course is likely to be stormy. There are, however, numerous exceptions and the studies by Conner and Holt in this connection are extremely interesting. In their series of 172 cases in which they were able to study the relation of the severity of the symptoms to the immediate prognosis, almost one-third of those who recovered were in the group with the extreme initial clinical manifestations. In spite of the apparent course, however, the future is indefinite. Experience teaches that recurrences are frequent and there is always the possibility of embolic manifestations from the detachment of a bit of the clot which forms on the endocardium at the site of the infarction. Finally, the course is dependent to a remarkable extent on the treatment of the patient following the occlusion. Even though the damage to the heart may not seem great at the time of the accident, the chances of recovery may be eliminated by allowing the patient on his feet too soon.

Treatment: The early stage is a critical period The protection of the heart at this time may not only determine the immediate outcome but have a deciding influence on the subsequent course. Moreover, there is always the possibility of complications as previously pointed out. The patient therefore should be confined to bed at as nearly absolute rest as possible and maintained in this state until the period of emergency has passed. Morphine is a most valuable remedy during this period of treatment and should be administered in sufficient amounts to control the pain and induce sleep. After the pain has disappeared, unless there is dyspnea, a simple sedative such as phenobarbital is usually effective in promoting relaxation and sleep. When there is significant cardiac embarrassment the administration of oxygen is indicated. The intravenous use of *theophylline ethylenediamine (0.48 Gm.) in 50 per cent dextrose so*lution is helpful in controlling the pain and commonly has pronounced effect on the dyspnea. This should be injected very slowly and may be employed two or three times during the 24 hours if the circumstances justify it. Instances have been observed in which this medication was a lifesaving measure. Digitalis is indicated in the presence of cardiac failure regardless of whether it develops early or late in the course of coronary occlusion When rapid action is desired a preparation for intravenous use may be added to the theophylline ethlenediamine and dextrose solution. If there are frequent premature contractions, quinidine sulfate 0.2 Gm. (3 grains) every four to six hours is advisable in order to ward off the possi-

bility of ventricular tachycardia It should also be employed in the presence of auricular fibrillation During the first ten days or two weeks it is highly important that the patient be spared all unnecessary physical effort Thus the bowels should be regulated by measures that will not produce frequent movements or entail undue strain in passing the stool The diet should be simple and of a character not calculated to promote abdominal distention It is ordinarily advisable to continue the bed rest 4 to 6 weeks and in some longer depending on the condition of the heart

The extent of the infarction is determined by the size of the vessel and the degree of collateral circulation It is possible to improve the collateral circulation by the administration of the theophylline or theobromine preparations The author uses theophylline ethylenediamine 0 1 to 0 2 Gm (1½ to 3 grains) three or four times a day beginning in the early course of the condition and continuing it until long after the patient is on his feet When rapid action is desired this medication is administered intravenously as pointed out above

The management of the patient after he is allowed out of bed is deserving of serious consideration Graded exercises serve an important function during this period of the treatment These should be carefully regulated and not extended to the point of shortness of breath or pain Thereafter it is a matter of regulating the habits of living so that the individual may as far as possible, stay within the limits of his cardiac disability In order to attain this objective it is necessary that the patient be told the nature of his disorder and the means of safeguarding himself Moreover, it is essential that he continue under the supervision of a physician

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CHAPTER XXI

THE DIAGNOSIS OF CORONARY INSUFFICIENCY

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Definition. Insufficiency of the coronary circulation may be defined as that condition in which the need of the myocardium for blood is greater than can be met by the amount which is delivered. This disproportion *between supply and demand can be brought about by a number of dif*ferent factors which either diminish coronary flow or increase cardiac work. Its commonest cause is disease of the coronary arteries.[1] Its two most important effects, which may seriously impair the functions of the heart, are anoxemia and ischemia of the myocardium. Acute local anoxemia, according to the current concept, is the chief cause of cardiac pain. Prolonged ischemia, in the sense of a quantitative reduction in coronary blood flow, may induce fibrosis of the heart muscle and result in congestive heart failure, usually affecting predominantly the left ventricle. In this section coronary occlusion will not be considered, since it is fully covered in Chapter XX. The discussion of pain will be limited *to the paroxysmal type commonly termed "anginal."*

CLINICAL ASSOCIATIONS OF CARDIAC PAIN

Among the clinical conditions causing cardiac pain due to coronary *insufficiency, the following are the most frequently encountered:*

1. **Diseases of the Coronary Arteries**
   (1) Atherosclerosis.
      (*a*) Slight, with patchy intimal change and loss of elasticity.
      (*b*) Marked, with calcification and narrowing or obliteration of the lumen.
      (*c*) *Occlusion, either atherosclerotic or thrombotic.*
   (2) Syphilis of the aorta, with stenosis or occlusion of one or both coronary orifices.
   (3) Periarteritis nodosa. This is relatively rare.

2. **Aortic Valvular Disease:** In aortic stenosis, less frequently in aortic insufficiency, the coronary blood flow may be diminished. In free aortic regurgitation this is believed to be due to the lowered diastolic pressure.

3. *Anemia:* The heart suffers from anoxemia along with the rest of the body.

4. **Paroxysmal Tachycardia:** The rapid rate may call for a greater coronary flow than is delivered

5. **Hyperthyroidism:** The increased metabolic demands of the body require a faster velocity of blood flow and an augmented volume output by the heart Cardiac work may exceed coronary reserve.

6. **Combined States:** For example, a person with coronary sclerosis will experience pain more readily if marked anemia is present than if the oxygen carrying capacity of the blood is normal. Ischemia and anemia complement each other in causing a higher degree of anoxemia.

It is apparent that pain, primarily of coronary origin, may be brought about by systemic as well as cardiac disorders. To define the etiology is of the utmost diagnostic importance.

DIAGNOSIS

SYMPTOMS

Advanced disease of the coronary arteries may be found at necropsy in persons who, during life, never experienced discomfort referable to the heart At the Mayo Clinic, in 86 consecutive cases of coronary sclerosis examined at the post mortem table, 10 per cent were of this latent type [2] In such hearts, there is presumably an adequate collateral circulation to compensate for the affected branches

Pain, when present, is often sufficiently characteristic to permit the diagnosis to be made from the history alone It is usually referred to the sternal region, sometimes a little toward the left side. Effort, emotion, eating and cold are familiar incitants. Discomfort is intense and ceases when the cause is eliminated There may be radiation to one or both arms, or to the neck and jaw Instead of pain, a sense of pressure in the chest, or of constriction, may be felt Other pain equivalents, or "substitution symptoms," as they have been called, are sudden weakness, dizziness, a short paroxysm of dyspnea, or nausea and vomiting. The sufferer frequently perspires during the attack and belches at its end. Reference of

discomfort to the epigastrium has resulted in confusing pain of cardiac origin with that due to various intraabdominal disorders, notably disease of the gallbladder.

It is essential that the physician who is responsible for management should discuss the symptoms with the patient. A history taken by a colleague, no matter how competent, cannot convey the same impression as that gained from a direct interview. From this personal contact is often obtained the key to the entire situation. And since *pain is so frequently* the only evidence of coronary disease, its precise description by the sufferer must be heard to be properly analyzed for appraisal of its significance.

SIGNS

There may be no objective evidence of disease. The heart may be normal in size and the sounds of good quality. The blood pressure is *frequently not elevated. The electrocardiogram may show no changes.* Yet the history is characteristic and subsequent events often quickly verify the diagnosis. The following case is unique in my experience because a completely negative physical examination, including the electrocardiogram, preceded sudden death by only 23 hours.

Case 1. A man, aged 49, was a stockbroker. His father and a brother *both died suddenly at the age of 50,* presumably *of coronary* heart disease. He had been unusually healthy and worked hard. He rarely took alcohol and smoked 12 or 15 cigarettes daily. For six months he had noted tightness in the chest on walking. The tubes in his lungs felt irritated. Three weeks after the onset the brother previously mentioned died of cardiac disease; this naturally upset him greatly. He was able to play golf but on hilly holes experienced a tightening just beneath the sternum. There was no radiation to the arms. Walking on the street caused substernal pain after going three or four blocks.

Examination showed slight retinal sclerosis but no thickening of the peripheral vessels. The blood pressure was 122/78. The heart was normal in size on percussion. The rhythm was regular, the rate 68. The sounds were of good quality and clear. Measurements of the orthodiagram showed no enlargement. There was no dilatation or tortuosity of *the aorta. The electrocardiogram was normal* (Fig. 1).

Because of the bad family history and the rather typical story, a diagnosis was made of coronary sclerosis. This was communicated to his family physician, who accompanied him to the office.

After the consultation he walked downtown and met his wife for *luncheon and a movie.* In the course of the picture he suddenly became

faint and broke into a profuse sweat. He took a cab to his home and went to bed. His physician saw him that evening but found no change in his condition. He had a *comfortable night*. He was again seen by his physician at 9.30 the following morning. He seemed comfortable and had had his breakfast. At ten o'clock he was smoking a cigarette when suddenly he gave a few gasps and was dead. Necropsy was not performed.

Often the heart sounds are weak. The first sound at the apex may be split, particularly if there has been a previous occlusion with myocardial infarction. A presystolic gallop frequently accompanies hypertension.

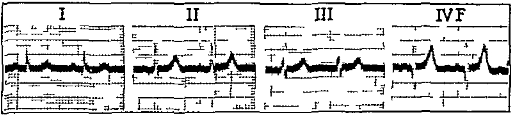

FIGURE 1. Case 1. Coronary sclerosis with anginal pain. Normal electrocardiogram 23 hours before sudden death.

Sometimes the electrocardiogram shows marked alterations when symptoms are mild or even absent. Such patients may live for long periods and carry on actively with their work. For 13 years I have had under observation a business executive whose graphic record has not *changed materially during this time.* *Auricular fibrillation, right bundle* branch block (of the wide S_1 type) and low voltage of Q R S have been persistently present. This patient is now 70 years of age and has been president and subsequently chairman of the board of a large corporation. *Small maintenance doses of digitalis control* the ventricular rate. His only discomfort has been slight substernal pressure when he hurries or indulges his fondness for a heavy meal.

If on radiologic examination cardiac enlargement is present and the aorta shows *atheromatous dilatation with or without calcification* support is lent to a suggestive history. If the electrocardiogram also is abnormal, the diagnosis is definite.

There are individuals who suffer intensely over a period of years from painful attacks having all the features of the anginal paroxysm. There are no signs of organic cardiac or vascular disease and no evidence of deterioration in the heart develops. One such patient had been subjected

to a variety of procedures including cholecystectomy, appendectomy and induction of the artificial menopause by radiotherapy Paravertebral injections of alcohol finally afforded relief Between seizures there may be no disability and strenuous exercise is possible without symptoms or apparent damage to the heart For want of a better explanation such cases have been regarded as instances of coronary spasm There is no sound evidence for so labelling them Yet the attacks when observed are real enough and present the features of a vasomotor crisis There is pallor sweating elevation of blood pressure and genuine suffering The cause is obscure but the patients are usually tense and high strung As in the following case the attacks sometimes are precipitated by a period of

diagraphic measurements of the heart were normal The anoxemia test presently to be discussed, was negative

In this case the response to the inhalation of ten per cent oxygen confirmed the clinical impression that the patient was not suffering from organic coronary disease It seemed probable that this was one of the relatively uncommon cases of coronary spasm initiated by nervous reflexes He was advised to continue to lead a normal life and to resume exercise His work was so arranged that he was spared unnecessary detail He was urged to take a winter and a summer holiday Above all he was assured that though uncomfortable the attacks were not of grave import. He has for the past year done extremely well

Case 3 In 1929 I reported such a case with post mortem examination [3] The man aged 43 was an electrician eager to return to work to support his wife and six children The pain was completely disabling and cervical sympathectomy then in fashion was undertaken by Dr Wilder Penfield *The patient died suddenly on the operating table* It was the general opinion that death was not due to the anesthetic. The final note by the pathologist Dr A M Pappenheimer stated that the necropsy disclosed no anatomical basis for the anginal attacks

DIFFERENTIAL DIAGNOSIS

There are various conditions which may cause pain referred to the chest or arms simulating that due to coronary insufficiency Such are

1 Acute serofibrinous pericarditis
2 Poisoning by tea coffee or tobacco
3 Aneurysm of the thoracic aorta
4 Intercostal neuralgia and pectoral myalgia
5 Duodenal ulcer
6 Cholelithiasis
7 Spasm of the esophagus or cardiac end of the stomach
8 Arthritis of the spine
9 Psychoneurosis with symptoms referred to the heart

If there is a possibility that one of these affections may be responsible for the discomfort suitable examinations will usually discover its presence or rule it out A cardiac neurosis sometimes presents difficulties The general demeanor of the patient the background of emotional factors the absence of all evidence of disease and the response to judicious psychotherapy usually serve to define the situation

There is a small but distinct group of individuals with normal hearts who experience pain because they are sensitive to caffeine, particularly when taken as coffee[4] Tea is less often responsible, probably because it is usually comparatively weak and not taken in large quantities These are high strung persons many of them under mental or emotional strain The susceptibility may be transitory suggesting that it is due in part at least to a lowered nervous threshold The character of the pain is different from the anginal type It is not severe is of relatively long duration and is not induced by effort or emotion It may radiate to one or both arms, causing a sensation of soreness When present it is not aggravated by exercise It is not relieved by nitroglycerin In spite of these distinguishing features, mistaken diagnoses have been made and patients have been alarmed and restricted in their activities without good cause Stopping the use of coffee and tea abolishes discomfort and on occasion saves a healthy person from becoming a cardiac invalid

Complaint of anginal pain has played a large role in claims for disability insurance It is a simple matter for a properly instructed subject to give a convincing history of painful seizures and even to feign attacks at opportune moments The form of the electrocardiogram can be modified by taking digitalis or urginin The racket exposed in New York City by the Federal District Attorney s office in 1938 showed the ease with which competent observers could be duped and large sums collected The author had the opportunity of helping the government in preparing the case and of testifying at the trial It was admitted on the witness stand that coronary sclerosis with paroxysms of pain could occur in the absence of all objective evidence of cardiac disease Phonograph records of the conspirators discussing their plans were obtained over tapped telephone wires There was a costly error in stamping two sections of the same electrocardiographic tracing with different dates And the testimony of a physician and three of the alleged sufferers who turned state s evidence, sufficed to convict the culprits

Disability policies are no longer written by the insurance companies And *total, permanent* disability due to coronary sclerosis and thrombosis is now recognized as an unusual circumstance[5] The use of the anoxemia test, now to be described, should be helpful in the detection of the malingerer as well as of latent coronary insufficiency

THE ANOXEMIA TEST

Various procedures have been tried to test the functional capacity of the coronary circulation. A *standardized exercise tolerance test* has been employed to precipitate anginal attacks under controlled environmental conditions.[6] The production of pain by inhalation of *gas mixtures low* in oxygen has also been attempted.[7, 8] But cardiac pain, induced either by exercise or by oxygen want, has proved unreliable as an index, partly because it represents a subjective end point, and also because so many complex factors are concerned in its production. Many patients with coronary artery disease, furthermore, do not experience pain.

The effect of exercise and of induced anoxemia on the form of the electrocardiogram in patients with coronary sclerosis has also been studied.[9] The difficulty in interpreting the significance of the changes observed has been due to the fact that these occur, in varying degree, in many persons without evidence of cardiac or other disease. The borderline between normal variation and pathologic response has not, until recently, been established by measurement.

In 1938, an apparatus was described for inducing oxygen want by enabling the patient to breathe a constant percentage mixture of oxygen *at a rate comparable to that of the normal pulmonary ventilation*.[8] Early in 1939, using a mixture containing 10 per cent oxygen and 90 per cent nitrogen, changes were described in the electrocardiogram following the induction of generalized anoxemia.[10] Criteria were evolved for normal and abnormal responses and it was suggested that certain characteristic and definable alterations in the electrocardiographic records could be used as an index of coronary insufficiency. A majority of the patients with spontaneous attacks of pain experienced similar discomfort within the 20 minute period during which the low oxygen mixture was inhaled. At the end of 20 minutes, or as soon as pain *was felt, the low oxygen mixture* was shut off and 100 per cent oxygen was administered for one minute.

The technic of the method has already been given in detail.[10] The test has now been performed over 500 times on normal persons and patients with various types of cardiac disease. No serious untoward results have occurred. On three occasions, early in the course of the work, pulmonary edema was produced; all of these patients recovered promptly with suitable therapy. But there is no hazard if the test is not given to patients with congestive heart failure or with recent myocardial infarc-

tion and provided it is not repeated in the same patient within 24 hours

Recent observations[11] have led us to alter slightly the criteria for an abnormal response given in the original paper. Added experience may call for still further modifications. The agreement between the clinical diagnosis and the result of the test though good has not been invariable. In certain patients regarded as suffering from coronary sclerosis the test has been negative. For this discrepancy there are at least three possible explanations: (1) The clinical diagnosis was incorrect; (2) the reduction in coronary reserve was not sufficiently great to be indicated by the test; (3) the lesions were in areas of heart muscle which were "silent" with respect to changes in the form of the electrocardiogram even when *anoxemia was induced. It has been shown that shortly after infarction* of the lateral or posterolateral wall of the heart there may be no electrocardiographic evidence of myocardial damage, though later necropsy reveals the presence of a large infarct.[12]

So far it has been possible to correlate the results of the test with necropsy findings in only two cases; in these the state of the coronary arteries afforded confirmation of the electrocardiographic changes. The recent experiments of Leslie Scott Jr. and Mulinos[13] *on cats* lend support to the observations on patients. After ligation of a coronary branch characteristic deviation of the R-S-T segments appeared in the electrocardiogram. In from 12 to 29 days these changes disappeared but could be reproduced by having the animals breathe a ten per cent oxygen mixture.

In normal subjects induced anoxemia tends to lower the amplitude *of the T waves in all leads; the T wave in Leads II and III may even* become inverted. Any one of the following alterations, in our experience to date, is a sign of coronary insufficiency:

CRITERIA INDICATING AN ABNORMAL RESPONSE

1. *The arithmetic sum of the R-S-T deviations in all four leads* employed (I, II, III and IV_F) totals 3 mm. or more.

2. Partial or complete reversal in the direction of T in Lead I if accompanied by R-S-T deviation of 1 mm. or more in this lead.

3. Complete reversal in the direction of T in Lead IV_F regardless of R-S-T deviation.

4 Partial reversal in the direction of T in Lead IV_F if accompanied by R S T deviation of 1 mm or more in this lead

The value of the test is best exemplified by presenting briefly two case reports together with the electrocardiograms

CASE 4 A male business executive aged 66 had always been high strung and fatigued easily There were no serious illnesses For many years he had vague digestive upsets usually associated with emotional disturbances He was first seen by his physician at the age of 61 because of burning in the epigastrium The electrocardiogram was normal Gastrointestinal x rays showed pylorospasm and this was the clinical diagnosis Because of persistence of symptoms and the possibility of early gastric neoplasm an exploratory laparotomy was done a few weeks later The findings were negative

At the age of 64 a two meter film of the heart showed slight left ventricular enlargement and an increase in the size of the ascending arch of the aorta The electrocardiogram showed minor changes in that left axis deviation had appeared and the T wave in Lead III had become isoelectric It was believed that these changes were no more than might be expected with advancing years.

At the age of 66 he began to have vague short precordial pains without squeezing or pressure These occasionally awakened him at night They were not related to exercise emotion or meals There was no dyspnea The blood pressure was 160/90 The heart was not enlarged on percussion The sounds were of good quality The rate was 60 There was a soft systolic blow at the apex There was no anemia

The anoxemia test shown in Fig 2 afforded definite evidence of a diminished coronary reserve The diagnosis of coronary sclerosis was made and the patient s life regulated accordingly In this case the patient s response to induced anoxemia was the deciding point in the diagnosis It seems probable that his symptoms from the outset were due to the cardiac condition

CASE 5 A male jeweler aged 45 was admitted to the hospital complaining of precordial pain He had enjoyed good general health He did not smoke and took almost no alcohol The attacks of pain began with a sense of fullness in the abdomen followed by substernal pressure occurring usually one half to one hour after eating There was no radiation to either arm Five weeks before admission because of a more severe paroxysm he was put to bed for four weeks and during this period had several milder attacks The admission diagnosis was coronary heart disease recent coronary thrombosis with myocardial infarction and possibly gallbladder disease

Examination showed no evidence of cardiovascular disorder The blood pressure was 124/88 The blood count was normal The electrocardiogram afforded no evidence of cardiac damage Films of the gall bladder after the administration of dye by mouth showed a faintly outlined gallbladder shadow with numerous non-opaque stones The anoxemia test shown in Fig 3 was normal

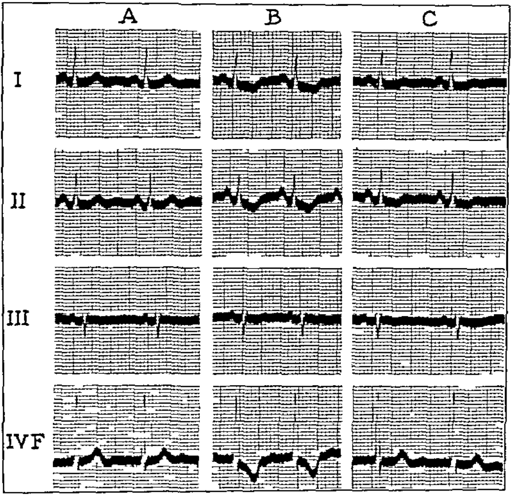

FIGURE 2 Case 4 Coronary sclerosis clinical diagnosis uncertain A Control *B* After inhaling ten per cent oxygen for 20 minutes in Leads I and IV F the T waves *have become inverted* and the R S T junctions depressed No cardiac pain was induced *C* After inhaling 100 per cent oxygen for one minute the form of the control has been resumed

The patient was operated upon The gallbladder was found to be chronically inflamed and filled with many mulberry stones Two years after operation he was free from symptoms In this instance the anoxemia test afforded confirmatory evidence that the symptoms were not of coronary origin

The anoxemia test, then, affords a relatively simple and entirely objective method for studying the efficiency of the coronary circulation It has proved of value in distinguishing cardiac pain from pain in the chest due to other causes as well as from pain referred from the abdomen When positive, it indicates diminution in the coronary *reserve* A *negative test,*

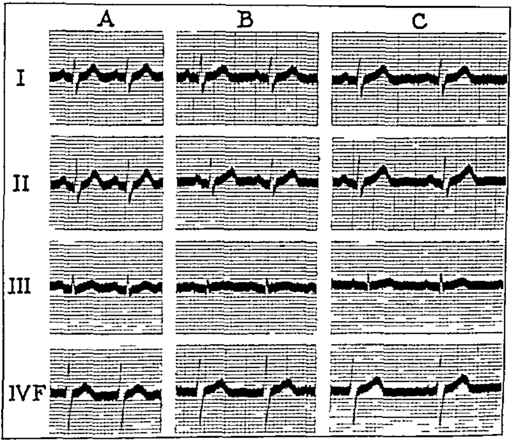

FIGURE 3 Case 5 Coronary sclerosis suspected cholelithiasis found *A* Control *B* After inhaling ten per cent oxygen for 20 minutes no significant changes No cardiac pain felt *C* After inhaling 100 per cent oxygen for one minute the record remains constant in form

however, does not rule out the presence of early changes in the coronary vessels or possibly, *of more advanced* lesions affecting a 'silent area of the heart As in the case of other diagnostic procedures, the result must be interpreted in the light of the clinical picture

CONGESTIVE HEART FAILURE

When congestive failure occurs in an elderly person without valvular heart disease and in the absence of hypertension, the basic pathology is

with rare exceptions, fibrosis of the myocardium resulting from atherosclerosis of the coronary arteries Anginal pain is more often absent than present The heart, as a rule, is enlarged The electrocardiogram frequently shows inversion of the T wave in Lead I, or Leads I and II, or bundle branch block The record occasionally is normal The heart sounds are apt to be weak and the heart rate rapid An apical systolic murmur is heard and a gallop rhythm is often present Radiography reveals pulmonary congestion and confirms cardiac enlargement The vital capacity is reduced and the pulmonary circulation time retarded

The symptoms of failure are insidious in their onset, once they have begun, they are apt to progress rapidly Dyspnea and edema may be extreme Arrhythmias are not uncommon, especially premature beats and auricular fibrillation Heart block and auricular flutter are more rarely observed.

Dyspnea resembling that due to myocardial insufficiency is sometimes seen in patients with advanced emphysema or extensive pulmonary fibrosis But in these conditions, unless the heart also has failed, the arm to tongue circulation time is not slowed This point is useful in differential diagnosis

Abrupt left ventricular failure may manifest itself by pulmonary edema or paroxysmal dyspnea (cardiac asthma) The immediate causes for such attacks are imperfectly understood But acute coronary insufficiency may be the precipitating factor when, for whatever reason, there is a sudden demand upon a myocardium that has little or no reserve supply of blood upon which to draw in an emergency Acute coronary insufficiency, with or without occlusion, also can induce ventricular fibrillation and so be responsible for sudden death [14]

CONCLUSION

The diagnosis of coronary insufficiency is a matter of considerable practical importance There are a number of causes for cardiac pain which must be distinguished with respect to etiology Various noncardiac conditions may simulate anginal pain so closely that differentiation is often extremely difficult Management and prognosis depend upon establishing the underlying cause of discomfort When congestive heart failure dominates the picture, recognition of the coronary etiology is usually comparatively easy

To urge optimism may seem strange when one realizes the enormous toll this disease is taking in our country, but from a selfish standpoint we should be optimistic. Such an attitude not only helps us to develop a satisfactory philosophy towards life while suffering from coronary disease, but also prevents our patients from becoming unnecessarily discouraged. If so discouraged, they may visit chiropractors, osteopaths, or Christian Scientists. These cultists may then tell them there is nothing wrong with their hearts and receive credit for successful treatment, since so often these patients can carry on useful, active lives for many years.

The head of one of the largest insurance organizations in this country said the other day, "It seems to me that most of the people you advise us to reject for life insurance because of their hearts act as pallbearers for the ones you tell us to accept." This is a challenge. It does seem natural for an individual who knows he is not 100 per cent healthy from a cardiovascular standpoint, to take such care of himself that he may live longer than the individual who considers himself sound. This was first brought home to me when I was working with Sir James Mackenzie in 1920 at St. Andrews in Scotland. He told me that he had his first substernal discomfort when he was 19 years old. When I was working with him he was 67 years old. At that time he was playing the No. 1 St. Andrews course in 84 and 86, and the rest of us were playing it in 120! He died finally of a coronary thrombosis at 73 years of age. Dr. Thayer

No examination or test can take the place of a careful history, obtained by the physician upon whom rests the responsibility for the patient's care. The electrocardiogram, if characteristic changes are present, is often the deciding feature in the diagnosis. When the history is equivocal, the physical examination negative and the electrocardiogram normal, the "anoxemia test" has proved helpful in demonstrating, objectively, diminution in the coronary reserve.

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CHAPTER XXII

CORONARY DISEASE INCLUDING ANGINA PECTORIS

WILLIAM D. STROUD, M.D.

Introduction: The subject of coronary insufficiency, coronary disease and angina pectoris should be a most interesting one, not only because the majority of the patients seen by a physician will sooner or later suffer with such a picture, but also because most physicians must expect to die with this condition. It therefore behooves us to learn as much as we can concerning its prevention and treatment.

Since coronary artery disease from a physiological and pathological standpoint has been covered in Chapter XX, this chapter will deal mainly with etiology and treatment. *One of its main objects is to leave with the physician a more optimistic attitude toward the future of individuals suffering with coronary insufficiency, coronary disease, angina pectoris or a healed coronary occlusion.* The term coronary insufficiency is included since there are many patients suffering from this syndrome due to pathology in the first part of the aorta or secondary anemia or advanced aortic insufficiency without actual coronary disease.

At this point I should like to stress the fact that usually the etiological factor in coronary insufficiency, coronary disease, angina pectoris or a coronary occlusion is one pathological picture, namely arteriosclerosis with or without hypertension. Many physicians still feel there is a different pathology producing the symptoms of angina pectoris, coronary sclerosis or coronary occlusion. Although this is still a debatable point, yet I feel it clears the situation if we consider the main underlying cause of this syndrome as arteriosclerosis and that the subjective symptoms of coronary insufficiency, angina pectoris or coronary occlusion are probably the result of the same type of underlying pathology manifesting itself in a *slightly different manner.*

To urge optimism may seem strange when one realizes the enormous toll this disease is taking in our country, but from a selfish standpoint we should be optimistic. Such an attitude not only helps us to develop a satisfactory philosophy towards life while suffering from coronary disease, but also prevents our patients from becoming unnecessarily discouraged. If so discouraged, they may visit chiropractors, osteopaths, or Christian Scientists. These cultists may then tell them there is nothing wrong with their hearts and receive credit for successful treatment, since so often these patients can carry on useful, active lives for many years.

The head of one of the largest insurance organizations in this country said the other day, "It seems to me that most of the people you advise us to reject for life insurance because of their hearts act as pallbearers for the ones you tell us to accept." This is a challenge. It does seem natural for an individual who knows he is not 100 per cent healthy from a cardiovascular standpoint, to take such care of himself that he may live longer than the individual who considers himself sound. This was first brought home to me when I was working with Sir James Mackenzie in 1920 at St Andrews in Scotland. He told me that he had his first sub sternal discomfort when he was 49 years old. When I was working with him he was 67 years old. At that time he was playing the No. 1 St. Andrews course in 84 and 86, and the rest of us were playing it in 120! He died finally of a coronary thrombosis at 73 years of age. Dr. Thayer of Baltimore told me that for the last ten years of his life, while carrying on a large consultation practice, not a day passed but that he had a cardiac warning Therefore, we are really justified in being optimistic. Our attitude toward sudden death from coronary occlusion has definitely changed in the last few years We used to believe that a great many cases of sudden death were due to coronary thrombosis This is true, of course, but recent statistics suggest that less than 25 per cent die suddenly in their first attack.

The following table well illustrates the increase in importance of cardiovascular disease as a cause of death We must realize that the number of deaths per thousand of population from cardiovascular disease is often greater than that attributed to the "heart," since cerebral vascular accidents, vascular nephritis and various types of fatal peripheral vascular disease are not included under "heart" in this table.

Pioneers in the Study of the Coronary Circulation

R V eussens first correctly descr bed the coronary vessels in 1715 In add ion he noted the d agnost c features of per card al effus on and *gave the first descr ption of aort c insufficiency* (1695) and m tral stenos s (1705)

Edward Jenner famous for discovery of vacc nat on aga nst smallpox was the first (w h C H Pa ry) to assoc ate coronary artery d sease w h ang na (1 68) *prov ng h s point when an autopsy revealed oss fied and* narrowed c ronar es in the heart of h s fr end, John Hunter

Heberden n 1 68 in a scholarly trea se gave the first clear cut cl n cal descr pt on of ang na pector s establ sh ng the cond on as a d sease en ty

Brunton, n 1871 not ng a r se of he blood pressure in some patients suffering from angina, was the first to successfully employ nitrites in the treatment of the condition.

Her ick (191) described corona y c lusion long regarded as an occasional necropsy finding and, separa ing it from angina, firmly established he fea ures of sudden obstruction of he coronary arteries as a clinical y recognizable syndrome

TABLE I

TEN LEADING CAUSES OF DEATH IN NEW YORK CITY, 1875 1930*

1875		1885	
All causes†	28 25	All causes	24 76
Pulmonary tuberculosis‡	373	Tuberculosis (all)	392
Diarrhea (under 5) §	316	Diarrhea (—5)	257
Diphtheria	294	Pneumonia	247
Pneumonia	212	Diphtheria	146
Smallpox	124	Heart	123
Violence	99	Violence	95
Heart	93 5	Nephritis	87
Nephritis	59	Cancer	51
Scarlet fever	54	Scarlet fever	45
Cancer	41	Typhoid	27
1905		**1930**	
All causes	18 32	All causes	10 76
Pneumonia	216	Heart	214
Tuberculosis (all)	238	Diarrhea (—5)	157
Nephritis	147	Cancer	116 5
Diarrhea (—5)	145	Pneumonia	115 6
Heart	144	Violence	81 8
Violence	109	Tuberculosis (all)	73 1
Cancer	73	Arterial disease	56 7
Diphtheria	38	Nephritis	41
Typhoid	16	Diabetes	25 6
Scarlet fever	12	Appendicitis	15 9

* This table was compiled by the Metropolitan Life Insurance Company of New York

† Death rates from all causes are per 1000 of population

‡ Death rates from tuberculosis and other causes except diarrhea are per 100 000 of population

§ Death rates from diarrhea under five years of age are based on the population under five

The following table possibly is one of the explanations for the apparent increase in coronary disease It was prepared by the Metropolitan Life Insurance Company and suggests that if one were born in 1911 one might expect to live to the age of 46 If one were born in 1930, one might expect to live to the age of 57 I suppose if one were born in 1939 now that the government is to take care of us, one may expect to live forever!

TABLE II

EXPECTATION OF LIFE AT BIRTH (METROPOLITAN LIFE INSURANCE COMPANY, INDUSTRIAL DEPARTMENT, 1911 TO 1930)

Year	Expectation of Years
1930	57 36
1929 •	55 78
1928	55 88
1927	56 12
1926	55 02
1925	55 51
1921	55 62
1923	51 55
1922	55 01
1921	55 08
1919–1920	51 11
1911–1912	16 63
Gain 1930 since 1911–1912	10 73

ETIOLOGY

One of the biggest advances in the prevention, diagnosis and treatment of cardiovascular disease in the last 15 or 20 years has been a recognition of the etiological factors so that now, no physician is justified in prognosing and treating a case unless he is as nearly positive as he possibly can be, of just what the etiological factor is These have now been narrowed to four main groups

1 Congenital
2 Rheumatic
3 Syphilitic
4 Arteriosclerotic (with or without hypertension)

We believe today there is no chronic cardiac damage from diphtheria pneumonia or thyrotoxicosis There are occasional cases of bacterial endocarditis due to gonorrhea or influenza but these are very rare, so that we feel that the above four groups cover the etiological factors which produce chronic cardiovascular disease This chapter naturally deals with group 4, arteriosclerotic cardiovascular disease with or without hypertension, since these are the patients who develop signs of coronary insufficiency and angina pectoris or a coronary occlusion

Dr. Stewart R Roberts[1] writes We call a syndrome essential angina pectoris, or essential hypertension or nervous indigestion, but in reality it can be explained on the basis of the spasm of muscle in different systems dependent, not primarily upon an organic or cellular pathology of that system, but rather upon the spasmodic aptitude and constitution of the individual As is the gear of the nervous system, so is the presence or absence of spasm The white man, particularly one living a life of stress in urban conditions of competition, work and strain, makes his little plans and lays up cares and riches and takes much thought of the morrow, the negro knows his weekly wage is his fortune, takes each day

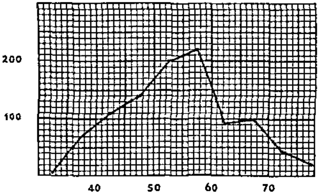


CHART 1 Age at first attack in all cases Review of 287 cases (Conner and Holt Am Heart J)

as it is, takes little or no thought of the morrow plays and lives in a state of play, hurries none and worries little What must it be to live unhurried, unworried, superstitious but not ambitious, full of childlike faith, satisfied, helpless plodding plain, patient, yet living a life of joy and interest?

This conception is an attractive one, but it has been qualified In a personal communication from Dr William Allen of Charlotte, North Carolina, he concludes from statistics and his own personal observation the following 'I suspect the patient, long suffering, noncomplaining hewers of wood and drawers of water have as much coronary disease as the white folks" At least it is thought that angina pectoris is less prevalent among the colored Dr Howard Sprague of Boston tells the story of two well known physicians visiting a plantation in the South, who met a negress over 102 years of age One doctor said to her, 'Now, Mandy, how come that you have been able to live here for 102 years when all your

friends and relatives have died so much sooner? Do you know why?" Mandy said, "Yes, I know why it is. When I sits I sits loose." I agree with Dr. Sprague. That is what we should all do if we have angina pectoris.

Dr. John Paul of New Haven tells me that his experience with the Indians in our Western states suggests that they also "sit loose."

We must remember that this is not a disease of old age. The largest incidence appears to be in the sixth decade with the peak around 57 years of age, as suggested by the chart on the preceding page.

Recently more and more cases are being reported in the fifth, fourth and even third decade.[3]

In 1930[4] I was bold enough to offer the following table as possibly including the main etiological factors in producing coronary insufficiency with ultimate coronary occlusion.

THE STORY OF THE DEVELOPMENT OF CORONARY DISEASE AND CORONARY OCCLUSION

In families with a history of the degenerative types of cardiovascular disease as the usual cause of death, an individual is born with a hyperirritable vasomotor system, i. e., a "spasmogenic aptitude."

This invidual is exposed to the necessary environment which may consist of

1. Frequent emotional upsets.
2. Infections (tonsillar, dental or other streptococcic infections)
3. End products of improper diet.
4. Insufficient intestinal and renal elimination.
5. Excess of nicotin, coffee, tea, and so forth.
6. Obesity or diabetes
7. Excessive or prolonged physical effort.
8. Long hours of nervous tension and mental concentration and inadequate vacations

CORONARY SCLEROSIS DEVELOPS

followed by

CORONARY OCCLUSION

Of course these factors are not original with me. They have been taken from the work of men most interested in attempting to discover the etiology of this condition

(1) It is pretty generally admitted that heredity plays a part in this picture. It may be possible, therefore, through a careful family history,

to find children who are potential coronary cases Although difficult, we may be able to steer these children through life without encountering too many of these etiological factors I realize it is practically impossible to prevent some of these factors from entering the picture

(2) It is still a debatable point as to whether or not frequent infections, and especially streptococcal infections, contribute toward the more rapid development of arteriosclerosis The main point in favor of this possibility has been the pathological picture of the coronaries seen in the hearts of children dying of rheumatic fever in the first decade of life

(3) There is much to be learned concerning the effect of diet upon the human organism and its relationship to hypertension and arteriosclerosis Cholesterol[5] and vitamin B are the most recent factors under discussion I think it is safe to say that very few physicians today believe that a salt free diet is indicated in this syndrome except in the presence of edema More recently it has been claimed that a low protein diet is not only of no value but may actually be harmful[6] If we reduce the protein in the diet below the average daily need of the body, it is suggested that this may cause anemia and a low plasma protein Since both of these factors may increase the permeability of the capillary wall, they may help to bring on congestive heart failure with edema, in patients suffering with hypertensive arteriosclerotic cardiovascular disease

(4) Most people in this country have been trained, through diet or medication, to insure a satisfactory daily intestinal elimination Personally I believe this is important, even if one must resort to a saline laxative for the rest of one s life The necessity for sufficient fluid intake has not been so well advertised, but I believe most people are conscious that in order to have efficient renal elimination there must be sufficient fluid taken into the body during the 24 hours

(5) It is a comfort to note that no one has been able to prove that alcohol plays much of a part in this condition In fact, I think most internists have decided that alcohol, in moderation is probably good for the average individual past middle life It certainly does not seem to be contraindicated in patients suffering with coronary insufficiency or angina pectoris and often will relieve the pain On the other hand, tobacco, especially in certain patients in this group, is definitely contraindicated Although tobacco never has been proven to be a factor in the develop

ment of arteriosclerosis, yet most people with coronary insufficiency have learned for themselves they have less pain if they give up smoking. One patient admits that if he smokes a cigarette after breakfast and then walks to the garage he will always have substernal pain. If he does not smoke a cigarette after breakfast and walks to the garage he never has substernal pain, and yet he goes on smoking! I believe, unless used to great excess, coffee and tea are not factors in either producing arteriosclerosis or producing symptoms in the presence of coronary insufficiency.

(6) Although thin people can have hypertension and coronary disease, yet I think these conditions are much more prevalent in the obese. Certainly patients with high blood pressure who are overweight can, in many cases, reduce their blood pressure by reducing their weight. With this reduction in weight the blood pressure will usually be maintained at a lower level for a relatively long time. With such reduction in blood pressure those that have angina of effort also seem to have fewer attacks. I have heard it said that insurance companies refuse more people for obesity than for any other one condition. Diabetics appear to develop arteriosclerosis more rapidly than nondiabetics, but since the introduction of insulin this point has been questioned. It is important to limit the reduction in the blood sugar in patients with diabetes who also have signs of coronary insufficiency, since the heart muscle depends to a great extent upon glycogen for its energy. It is especially important to maintain a normal blood sugar following acute cardiac infarction.

(7) As to excessive or prolonged physical effort, I believe this plays practically no part in the production of this disease. In my opinion there is no such thing as an "athlete's heart." The most reasonable explanation for many athletes dying from cardiovascular disease in their fifties and sixties is that they really are born with the "spasmogenic aptitude," or as Sir William Osler has it, "the proper tubing." It is this birthright which makes them good athletes, and they would most likely have died at the same age whether or not they took part in athletics. In other words, it is definitely questionable whether excessive physical effort plays any part in the development of arteriosclerosis with or without hypertension. This fact is well illustrated by the return of a Harvard crew to Cambridge for their class reunion. Each member of the crew was past 70 years of age and they had been out of college for 50 years. Not a single man on the crew had died except the coxswain!! It is reported that

he died of coronary disease. Of course physical effort must be regulated in the presence of hypertension or coronary insufficiency, but it is believed today that emotion plays more of a part in producing symptoms in these patients, than does physical effort.

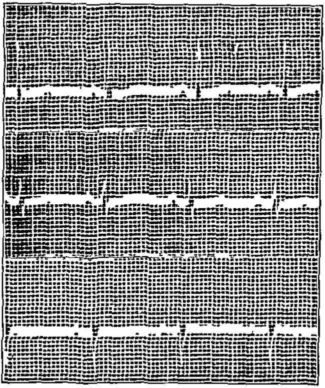


FIGURE 1 Electrocardiograms of G L., April 6, 1927 Left axis deviation (probably due *to patient's build) and T waves of low amplitude in all indirect leads*

(8) We must admit that long hours of nervous tension and mental concentration with inadequate relaxation and too few vacations, probably play a definite part in this syndrome. This is one reason that so many physicians develop this condition. For ourselves and for our patients more relaxation during the 24 hours and more frequent and longer vaca*tions are certainly indicated.*

For many years, the subject of the similarity of symptoms making necessary a differential diagnosis between heart disease and gallbladder disease has attracted a great deal of attention. There is no doubt that in some cases biliary colic may perfectly mimic angina pectoris and it is equally true that occasionally patients with coronary insufficiency will exhibit symptoms referred chiefly to the abdomen, indistinguishable

from those of gallbladder disease The following case history illustrates this point

Mr C L aged 49 years a musical comedy star leading an active life His family history is suggestive of a familial tendency to cardiovascular disease Seen on April 8 1927, he complained of substernal pain and breathlessness on exertion. Height, 5 feet 11 inches weight, 191 pounds

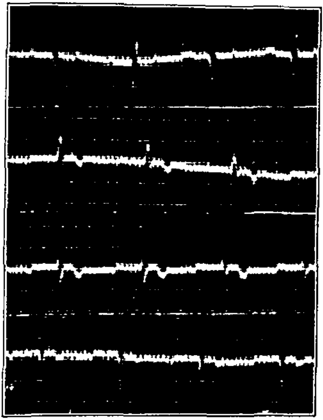


FIGURE 2 Electrocardiograms of Mrs A H August 2, 1933 Slight left axis deviation depressed S T_1, $_2$ and $_3$ and elevated S T_4 (old technic)

(of the high diaphragm type) pulse 76 blood pressure, systolic 112 diastolic 68 No murmurs detected but the aortic second sound was slightly accentuated and ringing in character suggesting some pathology *in the first part of the aorta*

Cholecystogram revealed a large gallstone and the gallbladder and stone were removed two weeks later The patient soon returned to an active life on the stage and worked without symptoms for eight years when on July 18 1935 he died suddenly from a myocardial infarct

This case suggests that the patient had coronary insufficiency and that the removal of the diseased gallbladder resulted in a prompt disappear

ance of symptoms and apparently in a lessening of the coronary insufficiency It seems possible that a diseased gallbladder may contribute toward the pain of cases with coronary insufficiency in much the same manner as does tobacco In other words, while not producing arterio

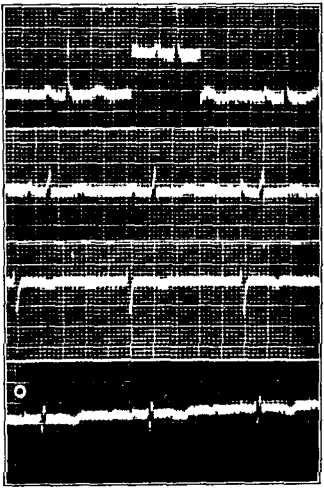


Figure 3 *Electrocardiograms* of Mrs A H June 30 1937 Left axis deviation T_3 and T_4 (old technic) about the same as tracing of 1933 T_1 and T_2 have become upright suggesting there may be a reversible effect of the gallbladder upon the heart

sclerosis, it may, as an added insult, produce subjective symptoms when *coronary insufficiency* already exists

Another case which illustrates the difficulty in differential diagnosis is as follows

On July 21, 1933, Mrs A H, an obese lady 63 years old while being treated for chronic bronchial asthma by *Dr J A Clarke Jr at the* Jefferson Hospital developed an acute epigastric pain with nausea and

all the usual symptoms of shock There was mild leukocytosis and a febrile reaction for three days The electrocardiograms 12 days later showed slight left axis deviation depressed S T$_{1}$ $_{2}$ and $_{3}$ and elevated S T$_{4}$ (old technic) She was diagnosed and treated as a case of cardiac infarction (refused gallbladder study)

November 15 1933 No subjective cardiac symptoms except fatigue Weight 185 pounds pulse 72 blood pressure—systolic, 110 diastolic, 88 Slight heave to the precordium but no murmurs (refused gallbladder study)

December 23 1936 Had heart attack in Monte Carlo when Italian Heart Specialist said I could not live through the night As he went out the door he left a card of an undertaker which he had with him!! I was pulseless

June 3 1937 Weight 203¼ pounds pulse 76 blood pressure—systolic 118 diastolic 88 Short systolic murmur at the apex and base The aortic second sound a little accentuated and ringing

January 2 1938 Attack of substernal and epigastric pain with shock Relieved in one hour by a hypodermic of ⅙₀ of heroin Two hours later still slightly shocked Pulse 80 blood pressure—systolic, 128 diastolic 88 Murmurs and aortic second sound as before Diffuse asthmatic rales throughout both lungs

October 18 1938 Died suddenly due apparently to an acute paroxysm of bronchial asthma *Autopsy* Heart normal in size except musculature of the right ventricle hypertrophied (8 mm) Considerable atheromatous and brittle calcium plaques involving the arch and descending aorta and the mouth of the left coronary showed a little sclerosis No evidence of cardiac infarction Microscopically some myocardial fibrosis *Gallbladder* distended and contains about 20 cholesterin stones varying in size from gravel to 1 mm in diameter Lungs suggest asthmatic death

This case illustrates how extremely difficult it is to differentiate between an attack due to gallbladder disease and an attack due to coronary insufficiency or even a coronary occlusion In my opinion after reviewing the history electrocardiograms and autopsy in this case all of these attacks were more related to the gallbladder than to the heart

In a personal communication to the author Dr I S Ravdin of the University of Pennsylvania writes as follows 1 Under ordinary conditions I believe gallbladder disease may be the primary lesion and the cardiac disease secondary 2 In the majority of instances I believe a pre existing heart disease is made worse by gallbladder disease 3 The

best results I have obtained in patients with coexisting gallbladder disease have been in those patients with angina. ¶ Properly prepared before operation and with adequate precautions during and after operation, the risk of surgery is not great. In my own series at the University Hospital in the last 54 patients with evident cardiac disease, in 22 of whom there had been signs of some heart failure, there was but a single

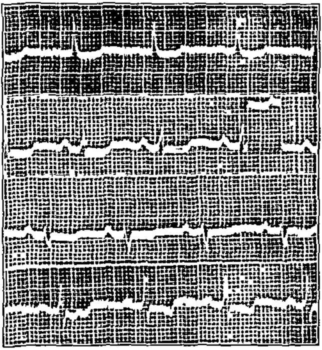


FIGURE 4 Electrocardiograms of Mrs A H January 1, 1938 Ventricular complexes and axis deviation the same as previous electrocardiograms Depressed S T intervals in all four leads (new technic) suggests a digitalis effect Patient had taken digitalis 1½ grains three times a day for 30 days but none for 72 hours before having the electrocardiograms at the suggestion of the family physician so that the digitalis would not affect the electrocardiograms ! [1]

death following operation in nonjaundiced patients I agree with Dr James White of Boston that patients with angina and gallstone disease had better have the gallbladder removed. In my experience the majority of these patients gain a great deal of relief.'

Although it confuses the issue, it is only fair to quote Dr H. L. Bockus of Philadelphia: "If the incidence of coronary disease is higher in males and the incidence of gallbladder disease is higher in females, how can there be any relationship from the standpoint of etiology?" This observation would suggest that gallbladder disease does not necessarily produce heart disease or arteriosclerosis, but it is still my impression that differ

entiation between attacks due to gallbladder disease and those due to coronary disease is often very difficult I also feel that in the cases suggesting coronary insufficiency the gallbladder should be carefully studied as there is considerable evidence that there is an effect upon the heart from the gallbladder which may be reversible if the gallbladder is removed [7]

TREATMENT

Treatment has been defined as the art or science of amusing a sick man with frivolous speculations about his disorder and of temporizing ingeniously, until nature either kills or cures him There is much to be said in favor of this type of treatment in cardiovascular disease and this is one reason we should be optimistic and encouraging so long as we protect the patient by regulating his daily routine so that he will only do the things we wish him to do and avoid the things we wish him not to do This I believe is possible in a majority of patients without telling them they have angina pectoris or have had a coronary occlusion The newspapers and periodicals are so full of these diagnoses that the average individual who knows he has had one or the other expects to drop dead any minute It takes an unusually philosophical mind to live happily under such circumstances and I feel physicians are producing more suffering through such fear than coronary insufficiency itself This is especially true in cases where such diagnosis is based on questionable electrocardiographic findings alone

In my opinion no doctor should tell a patient he has angina pectoris or a coronary occlusion except under unusual circumstances If a patient asks if he has angina pectoris say No you have had a temporary anoxemia of a portion of your myocardium or if a patient asks if he has had a coronary thrombosis say No you have had a relatively permanent anoxemia of a portion of your myocardium These statements are true and should certainly impress the patient with your vast knowledge If you then explain that at his age he has temporarily asked his heart to do a little more than it wishes to do he will probably follow your advice without the constant fear of sudden death

The eminent psychiatrist Dr W R Houston[8] of Austin Texas after spending most of his life in China has similar ideas concerning the Chinaman to those of Dr Roberts concerning the colored race It is he who deserves credit for the term spasmogenic aptitude to describe an appar

ently inherited prompt reaction to nervous and emotional stimuli. To quote him: "We have found ourselves forced to place it (spasmogenic aptitude) in the dim category of constitutional defects—constitution makeup, as it is of something inborn, something taken from environment. *The psychic, which means the most delicate of the mechanisms by which we make our adjustments to environment, is the best approach we have to the task of ameliorating evils that come from a spasmogenic aptitude.*" Coronary insufficiency, angina pectoris and coronary occlusion are, I believe, amongst these evils. In order to treat and prevent them, every physician must become a psychiatrist. This takes time and tact. He must often readjust a patient's entire life both at home and at work.

Dr. Houston further states that essential hypertension is virtually unknown in China; that he has never seen a case of angina pectoris in a Chinese, and if we should avoid spasm, we should be as the Chinese, "Ah yes, the Chinese lack the spasmogenic aptitude—placid, gentle, peace loving—Buddhist—their ideal, the serene calm of Amida Buddha, with closed lids and folded hands—symbol, the lotus flower scarcely swaying over the still pool."

The second most important form of therapy, the first being a sympathetic approach to the subject, is sedation. Most of these patients are poor sleepers and I believe they gain much from increased hours of sleep and relaxation. The average patient can take 8 to 16 to 32 mg. (1/8 to 1/4 to 1/2 grain) of phenobarbital, or an equivalent amount of sedatives, four times a day. This usually will act as a brake upon his reactions to various physical, nervous and emotional stimuli. His blood pressure will probably not rise quite so much and he will be more continuously relaxed. If possible, these patients should rest an hour either just after the noon meal or before the evening meal and of course the pernicious habit of a large evening meal should be stopped.

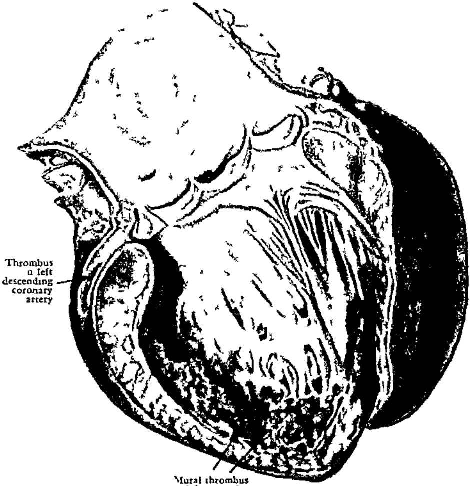
Patients with coronary insufficiency or the anginal syndrome can secure much relief from nitroglycerin. A low blood pressure is no contraindication to this drug as most patients with this syndrome do not develop the annoying symptoms which normal people develop, upon taking nitroglycerin. I believe nitroglycerin should be used much more frequently as a prophylactic. Many men who have previously had substernal pain on beginning an after-dinner speech, can prevent this by placing 0.6 mg. (1/100 grain) of nitroglycerin under their tongue just before rising

to speak. Others who have suffered with chest pressure and substernal pain upon walking a few blocks after a meal, can prevent this by placing 0.6 mg. (1/100 grain) of nitroglycerin under their tongue just before leaving the house.

Especially in the *presence of hypertension* attacks of *substernal pain* may disappear following prolonged bed rest with bathroom privileges for six months or more under pleasant circumstances and may not return for many months or years.

Whether or not the xanthin preparations help in this syndrome is still being debated. Certainly intravenously aminophyllin 0.259 Gm. (4 grains) will often relieve the pain of a coronary occlusion but usually morphine or dilaudid will do this alone. Most physicians give theophyllin ethylene diamine 0.095 Gm. (1½ to 3 grains) three times a day to these patients. More recently theobromine sodium acetate, 0.5 Gm. (7½ grains) three or four times a day has been advocated as less irritating to the gastrointestinal tract and just as efficient in its vascular dilating powers.

If all of the above measures are unsuccessful in preventing such a patient from becoming a total invalid, surgical procedures must be considered. The simplest of these, namely, paravertebral injections of alcohol is described in Chapter XXXVIII and finally the operations of Drs. Beck and Shaunessey can be considered. These operations are discussed in



Drawing showing characteristic thrombus lodged in left descending coronary artery and large mural thrombus in left ventricle Point of rupture of heart not shown (Coronary Thrombosis Its Various Clinical Features by Samuel A. Levine M D with the collaboration of Charles L Brown M D Medicine Williams & Wilkins Co Baltimore)

accompanying acute myocardial infarction is due to an infarct or to the morphine. Dilaudid, 2 mg. (1/32 grain), is apparently equivalent to 0.016 Gm. (1/4 grain) of morphine sulfate when given hypodermically and is becoming more and more popular and certainly in some patients it seems to be less nauseating. Although the symptoms of shock should be treated, yet I am impressed with the fact that these patients are too often disturbed by physical examinations and unnecessarily radical treatment. Nature is a great healer and perhaps the drop in blood pressure is an effort on the body's part to protect the myocardium. Especially in the presence of cyanosis, an oxygen tent or a B.L.B. Nasal Oxygen Mask may be of great comfort and sometimes apparently life saving.

The patient should be allowed to assume the position in which he is most comfortable, even if at times he insists on sitting on the edge of the bed or even in a chair. I also believe such patients, if they object strenuously to the bedpan, should be allowed to use a commode by the side of the bed. Of course the danger of such a procedure must be explained to the family, but I believe it is usually justifiable since for most patients the use of the bedpan places more strain on the cardiovascular system than sitting on a commode.

patients suffering with coronary insufficiency as manifested by substernal distress or the typical angival syndrome or a coronary occlusion. In the words of Sir William Osler "The best way to live a long and useful life is to develop a nice chronic disease and nurse it."

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CHAPTER XXIII

NOURISHMENT OF THE HEART BY CHANNELS OTHER THAN THE CORONARY ARTERIES

By SAMUEL BELLET M D

Introduction Nourishment of the heart by channels other than through the coronary arteries was first suggested by the work of Pratt[1] in 1898 His work together with the more recent observations of Kretz[2] Wearn[3] and Grant and Viko[4] has aroused considerable interest in the problem of cardiac nourishment The observation that the heart may be nourished by channels other than the coronary arteries has been given confirmation by the finding of hearts where both coronary arteries were occluded by chronic processes[1 2 5 6]

Although the occlusion had apparently been complete for many months the history of these patients revealed that they had been able to perform considerable work up to the time of death Death in these cases had usually been sudden Cases had also been observed at post mortem examination in which the mouth of one coronary artery was occluded by atheroma and the other coronary artery partially stenosed and yet according to the history the patients had been able to continue their work for a considerable period before death *The myocardial damage in these cases is much less than would be expected and infarction is often strangely absent*

There are three possible means of cardiac nourishment other than the coronary artery

1 The extracardiac anastomoses
2 The thebesian vessels
3 Reversal of flow in the coronary veins

The myocardial circulation can best be understood by following its embryological development The irrigation of the embryo s heart is first accomplished by the muscle being perfused through sponge like sinusoidal

spaces which receive their blood from the cavity of the heart itself It is these openings into the sinusoidal spaces, still persistent in the adult (although considerably narrowed and in some instances almost obliterated) that are commonly called venae minimae cordis, or the veins of Thebesius The next cardiac vessels to appear are the veins which branch into the substance of the myocardium Their development is followed by budding of the arteries which likewise ramify in the embryonic heart wall The finer terminations of both venous and arterial sprouts are capil

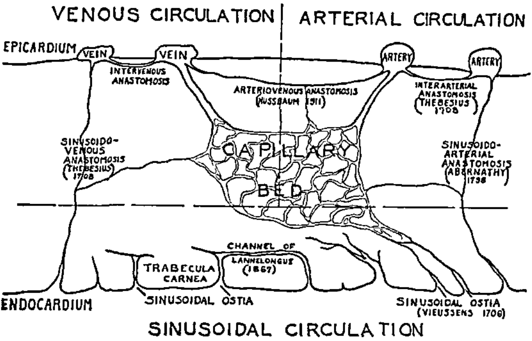

Diagram of myocardial circulation Diagram is based upon the embryological origin and adult distribution of vessels and the terminology employed is compatible with these points of view and with the terminology generally employed in the vascular system In development the endocardial sinusoidal system develops first the epicardial venous vessels develop next and finally the epicardial arterial vessels develop and join the other two forming a common capillary bed The endocardial or epicardial origin of the vessels as well as their various modes of interconnection are indicated in the diagram Sinusoidal ostia are present in all four chambers of the heart Intervenous anastomoses have long been common knowledge They are obvious with the naked eye Sinusoidovenous anastomoses have been recognized by Thebesius (1708) Verheyen (1712) Lancisius (1710 posthumous) von Haller (1786) Abernathy (1798) Bochdelak (1868) von Langer (1880) Pratt (1898) Nussbaum (1912) Kretz (1927) Wearn (1928) and Grant and Viko (1929) Sinusoido arterial anastomoses were described by Abernathy (1798) and by Wearn (1928) Arteriovenous anastomoses were described and figured by Nussbaum (1912) Interarterial anastomoses are reported by Thebesius (1708) von Haller (1786) Morgagni (1761) Senac (1749) Caldani and Caldani (1810) Krause (1879) Jamin and Merkel (1907) Spalteholz (1907 and 1924) and by Gross (1921) Sinusoidocapillary connections are recognized by Vieussens (1706) Thebesius (1708) Winslow (1776), Verheyen (1712) Lancisius (1740) Bochdelak (1868) Henle (1880) Hyrtl (1881) Langer (1880) Gross (1921) and Grant and Viko (1929) (Cyclopedia of Medicine F A Davis Co)

lary in character but true capillaries cannot be said to be present until the developing arterial and venous capillaries have joined with each other and with the sinusoidal (thebesian) circulation Now for the first time (in rabbit embryos of 17 mm in length at about the third week of fetal life) can blood follow the traditional elementary circuit of artery capillary and vein

The motion of a small artery ending in a capillary and this in turn drained by a small vein is an elementary one which peculiarly persists as far as the heart is concerned although for 300 years attempts have been made to show its inadequacy On the arterial side the presence of a rich anastomosis between the coronary arteries has been definitely established by the work of Spalteholz Nussbaum[8] and Gross[9] The maximum size of these connections is still in doubt but it is probable that they may attain an arteriolar size The presence of intravenous anastomoses is a matter of common knowledge Arteriovenous anastomoses* are known to be present elsewhere in the body and have been seen by Nussbaum[8] in the heart He believes that this system which he found in the epicardium serves to transmit blood from the arteries to the veins during systole when the capillaries are contracted The number and frequency of these anastomoses have as yet not been entirely worked out in the human heart (see illustration page 464)

I EXTRACARDIAC ANASTOMOSES

Von Langer[16] gave a complete account of the extracardiac anastomoses The most important extracardiac arterial connections seem to be the communication between the coronary arteries and the bronchial arteries through the capillaries of the vaso vasorum of the first part of the aorta and the pulmonary artery Because the occlusion of the ostia of the coronary arteries has been frequently accompanied by an obliteration of the lumina of the vessels for some distance beyond the point of origin the extracardiac connection with the vaso vasorum of the great vessels could not be essential for maintaining the circulation in these cases The capillary bed of the aorta in the region of the sinuses of Valsalva is so small that it would seem that such anastomoses could nourish at best but a small portion of the myocardium

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* Halpert[10] has reported a c[illegible] of ca[illegible] ac ar[illegible] [illegible] consisted in a [illegible]de comm[illegible]n[illegible]catio[illegible] between the aorta and the r[illegible]g[illegible] [illegible] and [illegible] as n[illegible] [illegible]ated [illegible] card[illegible]ac d[illegible]urbance dur[illegible]ng l[illegible]fe.

A third group of vascular channels which are believed to have considerable importance in the myocardial nutrition upon closure of the coronary arteries are the thebesian vessels.

II. THE THEBESIAN VESSELS

The discovery of thebesian vessels was credited to Vieussens,[11] but the first full description was by Thebesius[12] in 1708; since that time, many investigators, Haller,[13] Abernathy,[14] Bochdelak,[15] Langer,[16] Pratt,[1] Kretz,[2] Wearn,[3] Grant and Viko[4] have studied their anatomic connections and physiology. Their presence has usually been determined by the injection of various substances, air, water, mercury, waxes, celloidin, together with dissection or corrosion, and by perfusion experiments.

According to Grant and Viko,[4] there are three main types of thebesian vessels. These, however, merge one into the other. These are: (1) Vessels subdividing into trees ending in a capillary network and ramifying in the endocardium of the underlying muscle. (2) Channels uniting neighboring foramina, and showing all variations from fine anastomoses between neighboring trees and intertrabecular spaces. (3) Vessels uniting foramina with the coronary veins and showing all variations from fine anastomoses between the thebesian tree and coronary vein to direct communication of the coronary vein and the ventricle.

The ostia of the thebesian vessels are observed as small depressions or crypts in the endocardium of both auricles and ventricles. However, they are more numerous in the right ventricle, especially toward the apex and in the papillary muscles.

1. Embryology: The embryology and physiology of the intertrabecular or sinusoidal spaces have been investigated by Lewis[17] and by Grant.[18] Very early in embryonic development (in rabbit embryos 8.5 mm in length) the myocardium of the auricle is seen to be pierced by endothelial outgrowths which form capillary spaces between the muscle and epicardium. Similar outgrowths later appear from the outer portion of the ventricle, forming epicardial capillaries, which are extensions from previously existing intertrabecular spaces or sinusoids of the ventricles. Grant[18] found that in embryos of 17 to 20 mm. the intertrabecular spaces are present as wide spaces between the growing muscle bundles, but their continuation into the compact myocardium cannot be distinguished from the fine ramifications of the veins and arteries there, and all

three vascular structures together appear as a capillary network in that region

According to Lewis [17] further developments is marked by a continuous growth of the arteries and veins and by a regression of the intertrabecular spaces, the muscle columns coming together reduce many of the spaces to strands of epithelium without lumen * Grant[18] has been unable to satisfy himself that actual obliteration takes place It seems to be quite generally agreed that the sinusoidal circulation is replaced by the coronary circulation According to Grant [18] the outermost intertrabecular spaces are narrowed down by the compact myocardium to capillary tubes which are joined by the coronary vessels extending inward to the epicardium The capillaries arising from the central and inner intertrabecular spaces retain their connections with the ventricles The ventricular communications persist in the adult as the thebesian vessels of the ventricle

2 **Anatomic Connections and Physiology** The thebesian vessels connect the ventricles and the coronary veins by channels of very large size This has been shown very conclusively by the ease with which various preparations of thick consistency injected into the coronary sinus reach the ventricular chambers The connection between the coronary arteries and the ventricular chamber is still questionable Most investigators have been able to show only a capillary connection However Abernathy[14] and Wearn[3] believe that these connections are arteriolar in size

Where both coronary arteries have been occluded it is the belief that the myocardium receives its nourishment through the thebesian vessels If the occlusion is a gradual one, nutrition by this means would be favored Under such conditions the flow of blood would be away from the ventricular chambers into the coronary vessels The belief that the heart may be nourished by the thebesian vessels rests chiefly upon two series of experiments (1) The injection of various masses into dead hearts showing the connections by means of the thebesian vessels of the ventricles on the one hand and the coronary arteries and veins on the other and (2) the successful perfusion of the isolated heart through the thebesian channels

* Grant[19] and Bellet and Gouley[20] have each reported cases of a congenitally malformed heart in which there was a persistence of the sinusoids after fetal life Connections were traced by serial section between them and the coronary vessels.

Most authors supporting the theory of cardiac nourishment by the thebesian vessels believe that these channels are filled at the beginning of systole In view of the fact that double coronary artery occlusion was observed in certain specimens and in consideration of the work before mentioned the explanation of cardiac nourishment by the thebesian vessels was accepted as the only adequate explanation by which the heart could be nourished under such conditions

III NOURISHMENT BY REVERSAL OF FLOW IN THE CARDIAC VEINS

In the endeavor to determine the direction of blood flow in the cardiac chambers Batson and Bellet[21] performed a series of experiments in the intact animal whereby particulate matter was injected into the peripheral veins toward the heart The particles were of such size that they could not pass through the lung capillaries The particles were uniformly found in the coronary sinus and the cardiac veins Under the conditions of the experiment namely with a normal or a rising intraauricular pressure and a falling coronary artery pressure a reversal of flow occurred in the coronary veins It is well to remember in this connection that the valve of the coronary sinus is insufficient in 96 per cent of cases (Poirier and Charpy[22] and Yater[23]) These experiments suggested that in cases of double coronary artery occlusion with a zero pressure of the coronary arteries the flow of blood during atrial systole is toward the capillary bed They believe that the blood (under the conditions of the experiment) enters the cardiac veins during atrial systole from which it may flow in part into the ventricular chambers through the thebesian channels as well as into the capillary bed With the onset of ventricular systole the blood is forced from the capillary bed

It should be recalled that Pratt[1] was able to maintain the heartbeat for a considerable period by perfusion through the coronary sinus

That the heart may be nourished by venous blood is shown by the large number of congenital hearts where life is sustained for a considerable period of time by blood which is largely venous It is not difficult to understand how the nourishment of the myocardium can be maintained by venous blood when it is recalled that the oxygen tension of venous blood ranges from 60 to 70 per cent while the figure for arterial blood is 95 per cent.

These authors believe that the reversal of flow may be an adjunct in maintaining cardiac nourishment in cases of coronary occlusion. They also suggest that the reversal of flow in the coronary veins by irrigation of the formerly anoxemic areas could explain the relief of pain in angina with the onset of decompensation, and by helping to maintain the cardiac nutrition for a brief period, the occasional spontaneous recoveries from ventricular fibrillation.

IV. ARTIFICIAL PRODUCTION OF AN ACCESSORY CIRCULATION OF THE HEART MUSCLE

In view of the great incidence of coronary occlusion, various procedures, mostly experimental, have been tried in an endeavor to improve *the myocardial circulation in the presence of occlusion of the coronary* arteries. Hudson, Moritz and Wearn[26] observed widespread anastomosis of the auricular branches and the coronary branches to the pericardial fat and the pericardiophrenic branches of the internal mammary arteries and the anterior mediastinal, pericardial, bronchial, superior and inferior phrenic, intercostal and esophageal branches of the aorta. They were able not only by coronary injection to inject the surrounding structures but also to show vessels in the heart injected through the thoracic branches of *the aorta. They believe that this extracardiac collateral circulation is* probably of significance in compensating for sclerosis of the large trunk of the coronary arteries.

That the extracardiac anastomosis was increased by the presence of pericardial adhesions was shown by Moritz, Hudson and Orgain.[24] They observed a rich injection of the parietal pericardium and injected vessels were observed extending from the epicardium to the parietal pericardium. These studies suggested that the reserve for cardiac circulation would be increased by the presence of pericardial adhesions.

Encouraged by these results *Beck and his co-workers*[4, 9] *performed* experiments on dogs whereby a collateral circulation to the myocardium was produced by grafting tissue on to the myocardium. The principle consists of the vascularization of an organ by the establishment of a collateral arterial or arteriolar bed. It involves the union of blood vessels *that are too small for anastomosis by means of surgical suture.* It can be regarded as a type of *plastic operation*, the nearest approach to which is

the Talma Morison operation for cirrhosis of the liver The latter involves venous rather than arterial anastomosis

After successfully performing such an operation in dogs, Beck proceeded to operate on patients The operation consists in grafting a part of the pectoral muscle onto the myocardium The lining of the parietal pericardium is roughened everywhere so that it can become adherent to the myocardium Experimentally, in dogs it was possible to occlude completely the entire coronary supply except the septal branch, with recovery of the animal and without the production of infarction

To date Beck has operated on 25 patients about ten of these have died The results in the patients who survived the operation were at first quite encouraging Recent results however, have not come up to the original expectations

Other experimental methods for increasing the circulation of the myocardium have been attempted O Shaughnessy[29] has established a collateral occlusion in dogs and cats for coronary artery ligation by means of a pedicle *omental graft* Gross[28] has observed a conspicuous increase in the extent of the vascular bed after coronary sinus ligation in dogs

SUMMARY

In summarizing there are three possible means of cardiac nourishment in occlusion of both coronary arteries (1) The extracardiac anastomoses (2) by the thebesian vessels and (3) by the reversal of flow in the coronary veins The possibilities of cardiac nourishment from these sources is discussed The production of an accessory circulation to the heart muscle by engrafting part of the pectoralis muscle onto the myocardium at first attempted experimentally has recently been applied clinically with encouraging results

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CHAPTER XXIV

THE NORMAL HEART, ITS OUTPUT AND THE CIRCULATORY RATE

By JOHN T. KING, JR., M.D.

Introduction: The heart may be considered normal (L. *normalis*, from *norma*, rule or pattern) provided it conforms both in function and structure with the pattern determined from the examination of the hearts of healthy individuals. The limits of the norm, or standard, are established through *inspection, palpation, percussion, auscultation* and by special methods such as *roentgenography, electrocardiography,* determination of *arterial* and *venous pressures, polygraphy,* determination of the *circulatory rate, cardiac output* per minute, and *tension of the blood gases.*

1. INSPECTION

Inspection of the normal individual usually indicates the absence of such signs of circulatory or cardiac disorder as cyanosis, dyspnea, orthopnea, and edema of the dependent parts. Peripheral pulsation, the degree of which can be delimited for the normal subject only by examination of many healthy individuals, may usually be seen over the carotid arteries, under the outer ends of the clavicles (subclavians), in the episternal notch (innominate), and frequently over the brachial arteries, especially in elderly subjects. Rarely, the radial pulse is visible. While the venous pulse in the neck consists of three waves, *a, c,* and *v,* only two are distinguishable customarily with the naked eye, *viz., a* and *c*; deviation from the normal appearance of the jugular waves may throw important light upon the condition of the heart. Certain normal individuals, especially under conditions favoring peripheral vascular relaxation, show capillary pulsation.

While the anatomical position of the heart valves has no direct relation to inspection, it is well to be familiar with their location as projected

anteriorly upon the chest wall The position of the anatomical valve areas on the chest wall is about as follows *Pulmonic,* in the second left inter space at the sternal border *aortic* under the left half of the sternum at the lower border of the third costal cartilage *mitral,* between the sec ond and third costal cartilages and between the left half of the sternum and *one inch to the left of the sternum according to various observers* the *tricuspid* behind the sternum between the levels of the fourth and fifth costal cartilages The mitral valve is the farthest from the pulmonic the nearest to the anterior chest wall (Norris and Landis[20])

The precordium is relatively prominent upon the chest wall in about one of each four normal individuals allowance should be made for this normal deviation from the average chest conformity in estimating the *prominence due to such conditions as cardiac hypertrophy* pericardial effusion aneurysm or pleural effusion The *point of maximum intensity* of cardiac impulse (P M I) may be found in most individuals in the fourth interspace when recumbent in the fifth when erect Unless there be an unusual body configuration the P M I in health is not over 9 cm *to the left of the midsternal line it is usually less according to the size* of the subject The impulse in this region is usually caused by right ventricular thrust though the left ventricle forms the anatomical apex *of the heart When the subject assumes the left lateral decubitus the* heart falls toward the left and the P M I may shift laterally approximately one half as far as it had been distant from the median line when the subject was supine

With the patient in the right decubitus the P M I moves toward the midline and its distance therefrom is usually about one half as great as when the patient is supine Pathological displacement of the P M I may be caused by one or more of various conditions of the heart mediastinum pleural or abdominal *cavities Normally the impulse may be masked* by a thickened chest wall (obesity) or by overlying lung (emphysema) It may be exaggerated in a patient with a thin chest wall or in the pres ence of rapid forceful heartbeat caused by exercise fever or the use of tobacco or coffee While the P M I consists of a propulsive thrust it should be remembered that retraction may occur normally *inside* the P M I and *in the interspace above it* The impulse itself consists nor mally of a single systolic forward thrust there being no visible cardiac movement in diastole

2. PALPATION

The initial palpatory procedure should consist of laying the hand flat against the precordium so as to include the P.M.I., allowing the fingers to conform to the contour of the chest. Such examination throws light upon the general activity and size of the heart and aids in locating the P.M.I., which may be found more accurately through careful palpation with the finger tips. Shocks produced by closure of valves and thrills can be distinguished best by means of the rigid palm of the hand: The fingers should be hyperextended as far dorsally as possible, thus permitting the vibration to be transmitted to the bones of the hand. Following exercise or other stimulus, a normal heart may transmit a certain distinct jar to the hand palpating the P.M.I.; such a phenomenon, however, lacks the truly snapping and clearly cut quality such as is found in mitral stenosis. A tapping impact associated with a normal heart may be felt over the pulmonic valve area in emphysema or other obstructive pulmonary condition, such a shock is synchronous with a second sound. In the presence of hypertension, congenital stenosis of the aorta or aneurysm, a diastolic shock may be felt at the aortic area, though the heart may otherwise be normal. A true thrill is a vibratory sensation (described by Laennec as a cat's purr) that is associated with various cardiac diseases; the normal heart may, under excitement, cause a fine vibratory sensation to be transmitted to the palpating hand during systole, but this is rarely sufficiently pronounced to suggest the thrill of cardiac disease

3. THE PULSE

For purposes of convenience, the radial pulse is examined in preference to that of other vessels, and such examination may throw valuable light upon the condition of the heart. Examination should be made with the finger tips and the following qualities noted: *Volume* of the vessel itself and of the pulse wave, *rhythm, tension, rate* per minute, special characters of the pulse and condition of the *vessel wall;* finally, a comparison of the two radial pulses is made. In the consideration of such features of the pulse as volume, tension, and special characteristics, it is well to remember that the volume and tension and many of the distinguishing qualities depend upon: (1) The rate of cardiac contraction and the volume of ventricular output with each systole; (2) the degree of elasticity of the arterial walls and the patency of the lumen; (3) the degree of peripheral resistance.

(a) Volume: By volume is understood the apparent size of the pulse wave as it passes the palpating fingers. Volume may be modified in health under various conditions; for example, it may be small under conditions favoring vasoconstriction such as chilling, or large after exertion or excitement and under conditions favoring peripheral vascular relaxation.

(b) Rhythm: Arrhythmia is found commonly in normal hearts, especially among children. That most frequently encountered consists of acceleration during inspiration, retardation during expiration—normal respiratory irregularity; this type may be recognized from its disappearance when the breath is held or after paralysis of the vagus effect from atropine. Arrhythmia independent of respiration is sometimes found, especially in children, and may suggest the complete arrhythmia of auricular fibrillation. Intermittent pulse, due to precocious cardiac systole ("extrasystole") is common among normal individuals; the condition is often most pronounced when the individual is resting (as after retiring) or after excitement, fatigue, or as the result of constipation, distention, pregnancy, or excessive use of coffee, tea or tobacco. Precocious systole following each normal contraction of the heart causes bigeminal pulse, provided the premature beats reach the wrist. If the premature contraction occurs after each two normal systoles, or if two premature contractions follow regularly after one normal systole, a trigeminal rhythm is established. As a general rule, a premature contraction of ventricular origin is followed by a pause that is roughly as much longer than the usual diastolic pause as the preceding premature systole was premature. Such a prolonged diastolic pause is spoken of as a "*compensatory pause*." Auricular premature systoles are followed by an incompletely compensatory or by a normal diastolic rest period. Premature systole is not uncommon among normal individuals. Predisposing factors are excitement, tabagism, fatigue, gastrointestinal disturbances, pregnancy, pulmonary disorders, and overindulgence in tea or coffee. They are common among infants during the first few days of life (Hamilton[11]).

In general, arrhythmias of functional origin tend to diminish or disappear following exercise, while this is not true of the more serious arrhythmias such as auricular fibrillation.

(c) Tension: The propulsive power of each cardiac ejaculation, together with the resistance of the peripheral vascular bed and the elasticity of the arterial walls, produce a considerable degree of pressure within the arteries. To estimate tension, the pulse is felt with the fingers of both hands; pressure is exerted with the fingers of the proximal hand until the pulse is no longer palpable with the distal hand. The pressure necessary to compress the pulse indicates the arterial tension.

(d) Rate: The rate of the pulse at rest is given by Peterson and Walter[21] as 66 per minute for normal men and 71 for women, these figures having been derived from more than 2500 observations on about 1200 subjects The pulse is normally more rapid in childhood, following exercise, or under conditions of mental excitement. Fever usually accelerates the pulse rate to a degree of about ten beats per minute for each degree of fever (F). Paroxysmal tachycardia may occur in an individual with an otherwise normal heart

Special types of pulse, which may be present to greater or less degree in normal persons, have given rise to the following nomenclature:

Pulsus magnus (large), *parvus* (small), *celer* ("quick," with sharp rise and fall), *frequens* (rapid rate), *rarus* (slow rate), *bigeminus* (coupled), *trigeminus* (triple), *dicroticus* (with dicrotic wave), *anacroticus* (with anacrotic wave), *deficiens* (with rate less than that of the heart), *recurrens* (possessing reversed blood flow), *plenus* (full), *vacuus* (weak), *irregularis perpetuus* (completely irregular), *durus* (firm, well-sustained), *bisferiens* (having two waves, separated by more than one-tenth of a second, to distinguish it from dicrotism).

(e) Vessel Wall: No examination of the pulse is complete without palpation of the vessel wall. Atheromatous changes are indicated by increased rigidity of the vessel, with tortuosity and palpable calcium deposits, causing a "goose-neck," or nodular vessel.

4. PERCUSSION

The precordial area is percussed for the purpose of determining the extent of deep cardiac dullness which marks the approximate border of the heart, and the superficial cardiac flatness which represents that portion of the heart not covered by lung. In outlining the deep dullness, *mediate* percussion may be used. In this method the percussing or *plexor* finger strikes a finger of the other hand known as the *pleximeter*. Or,

immediate or *direct* percussion may be employed, the stroke being made with the finger tips directly against the chest wall Either method is suitable though indirect percussion is the rule The pleximeter finger is first laid against the chest wall parallel to the expected border of the heart at a point well outside the probable limit of dullness The examiner taps the pleximeter finger with the plexor finger moving the pleximeter finger gradually toward the heart *The percussion note or normal lung* resonance becomes duller as soon as the pleximeter finger reaches the cardiac border The size of the normal heart will be described later in the chapter on *Roentgenology of the Heart and Great Vessels,* in this volume Percussion may not be expected to permit the delimitation of the heart with less than 0 5 to 1 cm error on each border left and right In adults the normal cardiac dullness should not extend more than 10 cm *to the left or more than 4 5 cm to the right of the midsternal line though* there may be a slight exaggeration of these measurements in individuals whose hearts lie more than ordinarily in the transverse position due to some such condition as abnormal obesity or distention

The superficial cardiac flatness can be delimited only through very light percussion In normal individuals a portion of the heart roughly as large as a silver dollar is not covered by lung hence percussion of *this part of the precordium produces a perfectly flat note This area begins at the junction of the fourth left rib with the sternum and extends* outward and downward in a convex curve

The relative value of various methods for estimating the position of the left border of the heart was discussed by Luton [17] who compared the clinical localization of the apex by inspection and palpation with percussion of the left border and roentgenogram (7 foot technic) Comparison of percussion and roentgenogram of the left border in 82 cases showed an *average difference of 1 5 cm in measurements of individual cases by the two methods* In certain cases in which x ray examination was not practicable, localization of the apex by physical signs was found satisfactory In a series of 30 cases roentgenograms showed the heart s shadow beyond the palpated P M I in 19 while in 11 the P M I lay outside the cardiac shadow Luton concluded that determination of the left border by palpation of the apex and percussion *is of value in addition to x ray measurements*

Auscultatory Phenomena of 500 Supposedly Normal Hearts

	No. Cases	Per Cent
Third heart sound	118	23.6
Reduplication of first sound at apex	16	3.2
Systolic apical click	2	0.4
Systolic murmur at apex present in recumbent posture, absent in erect posture	65	13.0
Cardiorespiratory systolic murmurs limited to inspiration		
At apex	16	3.2
At conus arteriosus	4	0.8
At aortic area	3	0.6
Cardiorespiratory systolic murmurs present in both inspiration and expiration		
At apex	13	2.6
At conus arteriosus	5	1.0
At aortic area	2	0.4
Accidental systolic murmurs		
At conus arteriosus	70	14.0
At aortic area	31	6.2
Cardiorespiratory diastolic murmurs		
Near aortic area	3	0.6
Near conus	1	0.2
Near apex	0	0.0
Extrasystoles	9	1.8
Reduplicated second sound at conus area	23	4.6

(b) Systolic Click. Occasionally a sharp superficial dry clicking sound is heard at or near the P.M.I. It may occur at any time during systole. While it is not affected radically by inspiration, it does occasionally disappear when the subject is supine, which lends strength to the writer's impression that it is an accidental extracardiac phenomenon. Though it may be found rarely after acute pericarditis, it has no apparent

Hamilton[11] studied certain physiological peculiarities of the heart in infancy and childhood. He points out that the left ventricle, about equal in size to the right at birth, becomes approximately twice the size of the right ventricle at the end of the first six years of life.

5. AUSCULTATION

A binaural stethoscope, fitted with a bell or diaphragm chest piece or with both, is most suitable for the auscultation of the heart. To be disregarded are: Noises from without (to exclude which, the earpieces must be sufficiently large to fill the external auditory canal completely); skin friction sounds; hair sounds (vaseline may be applied if necessary to mask friction against the hair); joint sounds from the examiner's fingers or from the patient; muscle sounds (the patient must be relaxed, warm) and the superficial slap of the heart.

(a) Sounds: The sounds of the heart are usually two, traditionally represented by the syllables "lub" for the first and "dupp" for the second sound. Systole, which occupies the period after the first sound and before the second, lasts for approximately 0.37 second, while diastole is about 0.48 second in length, varying with the heart's rate. A third sound, found by Thayer[24] in 50.9 per cent of young adults, was present among healthy soldiers (King[12]) in 23.6 per cent. This sound is soft, low-pitched and is best heard with the subject supine or in the left lateral decubitus. It is most clearly audible at the P.M.I. or just inside, and is associated in some manner with ventricular filling (end of "active diastole," about 0.13 second after the beginning of the second sound).

A well marked third sound may be mistaken for: First, an early diastolic rumble of mitral stenosis; second, the so-called "opening click" of mitral stenosis; third, the sound associated with the elastic recoil of the heart from the chest wall in adherent pericardium; fourth, the reduplication of the second sound due to asynchronous closure of the aortic and pulminary valves. Asynchronous closure of such valves causes a reduplication of the second sound best heard at the pulmonary area, while the normal third sound is heard best at the apex or over the lower precordium. Moreover, the interval between the two elements of a split second sound is not so long as that between the normal second and third sounds. Finally, the protodiastolic gallop. The third heart sound and the protodiastolic gallop cannot be differentiated from one another by auscultation; in fact, it is

likely that they are produced by a similar mechanism namely the sudden tension of the ventricular walls at the end of filling early in diastole As a rule a normal third sound is a sign of youth and normality When a similar sound is heard in association with signs of heart disease it is known as a protodiastolic gallop

The first sound at the apex may be exaggerated as a result of exertion fever and nervousness and is normally louder in young people than in older The pulmonic second sound is usually louder than the aortic before 20 years of age between 20 and 30 the predominance of one sound over the other is about equally frequent after 30 the second aortic sound is usually louder

Reduplication of either first or second sound may occur in health Reduplication of the first is uncommon (about three per cent) and is apparently *due to impact of the heart against the chest wall* it usually disappears or becomes less marked when the subject lies upon the back Such reduplication consists of two rather loud sounds of approximately equal intensity

This form of reduplication differs from presystolic gallop in two respects Its variability with change of position which does not affect presystolic gallop rhythm and the fact that two relatively intense and equal sounds are heard while in presystolic gallop the first element is usually relatively soft In normal reduplication of the first sound the two elements are rather loud while it is characteristic of bundle branch block that the reduplication of the first sound produces elements that are faint or inaudible

At times a normal presystolic sound may be heard (Bridgman[4]) the sound usually below the level of audibility follows shortly (0 02 second) after the beginning of auricular contraction and precedes the first sound by about 0 01 second It may be associated with tension of the ventricular walls Reduplication of the second sound is common in health especially during deep respiration As a rule it is probably due to a retardation of right ventricular emptying with delay in closure of the pulmonic as compared with that of the aortic valve

During the World War in the course of examination of soldiers on active duty King found various auscultatory phenomena the frequency of incidence of which is shown by the table that follows

AUSCULTATORY PHENOMENA OF 500 SUPPOSEDLY NORMAL HEARTS

	No Cases	Per Cent
Third heart sound	118	23 6
Reduplication of first sound at apex	16	3 2
Systolic apical click	2	0 4
Systolic murmur at apex present in recumbent posture absent in erect posture	65	13 0
Cardiorespiratory systolic murmurs limited to inspiration		
At apex	16	3 2
At conus arteriosus	4	0 8
At aortic area	3	0 6
Cardiorespiratory systolic murmurs present in both inspiration and expiration		
At apex	13	2 6
At conus arteriosus	5	1 0
At aortic area	2	0 4
Accidental systolic murmurs		
At conus arteriosus	70	14 0
At aortic area	31	6 2
Cardiorespiratory diastolic murmurs		
Near aortic area	3	0 6
Near conus	1	0 2
Near apex	*0*	*0 0*
Extrasystoles	9	1 8
Reduplicated second sound at conus area	23	4 6

(b) Systolic Click Occasionally a sharp superficial dry clicking sound is heard at or near the P M I It may occur at any time during systole While it is not affected radically by inspiration it does occasionally disappear when the subject is supine which lends strength to the writer s impression that it is an accidental extracardiac phenomenon Though it may be found rarely after acute pericarditis it has no apparent significance

If such a click is rather loud it may give the examiner the impression of being a true murmur On the other hand certain true murmurs consist of a series of sharp clicks and sound very much like a series of normal systolic clicks As a rule a single click may be considered normal If they are multiple they probably represent a true systolic murmur

(c) Sternal Crunch Either heart sound or both of them may be associated with a superficial crunching sound when the stethoscope is

placed at the lower left border of the sternum This has been described by Blumer[1] and is supposed by him to be due to friction of the heart against certain superficial structures, notably the pericardiodiaphragmatic ligament This sound may be prolonged into a squeak closely resembling a murmur and may be mistaken for the murmur of mitral insufficiency The crunch is heard best when the subject leans forward and its intensity is decreased, as a rule, when the supine posture is assumed it may disappear altogether in this posture The fact that the sternal crunch is at times quite loud over a dilated or hypertrophied heart has led some observers to the fallacious assumption that the sound is an indication of heart disease however, the frequent occurrence of the crunch among perfectly normal individuals leaves no doubt that it is of no pathological significance The crunch may also be particularly intense in individuals with flat or funnel chests

The commonest misinterpretation of the sternal crunch lies in considering it a true pericardial friction rub Its behavior as indicated above should help in avoiding error

(d) Normal Murmurs An apical murmur heard with the subject in the recumbent posture is not uncommon its prompt disappearance when erect places the murmur at once among normal cardiac phenomena It gives the distinct impression of originating within the heart and Thayer[25] has raised the question of whether it may be due to a real but slight mitral incompetence that is to be considered physiological in certain individuals

Cardiorespiratory murmurs limited to inspiration, may be heard at *apex or the base, outside or just inside the apex, and in the left lower* thoracic region behind They are caused by impingement of the heart as it moves in systole against the lung, causing a systolic accentuation of the inspiratory breath sound They are apt to be loud over the lingula pulmonalis, just inside the cardiac apex, and are usually best heard with the subject erect They may disappear altogether when the supine position is assumed As a rule they disappear when the breath is held in inspiration, if they do not disappear, they are sufficiently modified by this procedure to allow recognition Any murmur limited to the inspiratory phase of respiration should be considered to belong to the category of cardiorespiratory murmurs

Certain vascular murmurs may be so intense over the precordium as to suggest a valvular lesion, even though the heart be normal The writer has known the systolic murmur of coarctation of the aorta which is best heard in the left interscapular region to be sufficiently loud over the precordium as to lead to the diagnosis of mitral insufficiency due to rheumatic endocarditis The murmur of patent ductus arteriosus while closer to the heart than the murmur of coarctation is usually rougher more continuous and of a more machinery like quality

SPONTANEOUS EMPHYSEMA OF THE MEDIASTINUM

Case of J B white aged 41 Baltimore City Hospitals No 45423 This patient entered the hospital June 7 1939 suffering from severe pain in the chest He had been exposed to contact with a tuberculous brother in law five years ago following which he had three chest roentgenograms made all being negative Ten days before his admission he had been discharged from the same hospital where he had been treated for a lacerated wound of the left hand and traumatic amputation of the fourth and fifth fingers This injury was acquired in an automobile accident but there was no note of trauma to the chest at the time Two hours prior to the present admission while resting about noon the patient developed a sudden severe pain behind the sternum This was associated with severe dyspnea because of which he felt it necessary to walk about He was faint his skin warm and moist but he was not nauseated The pain remained in the mid chest and did not radiate Its severity was rather constant though it was somewhat aggravated by deep respiration This patient told the writer that he was conscious of some degree of division of the pain into two foci one on either side of the sternum Admission temperature 37 5° C (99 6° F) Between 18 and 24 hours after onset the temperature was 37 9° C to 38 1° C (100 2° F to 100 6° F) On the third morning it was normal and remained so On the recent prior admission to the hospital the blood pressure had been 130/78 On the present admission it was 110 120/60 70 There was no history of rheumatic fever excessive tonsillitis or allied infections

Physical examination was normal except about the precordium Here was heard a peculiar loud crunching sound having both systolic and diastolic components the systolic being louder The sound was best heard in the third and fourth interspaces just left of the sternum It was greatly accentuated with deep inspiration and when the patient turned on his left side On expiration it was somewhat diminished The examinations of blood urine and stool were normal though the sedimentation rate was 18 mm per hour corrected The serologic test for syphilis was negative The roentgenogram of the chest showed heart and lungs

normal separation of interlobar lines on the right and a shadow on the left cardiac border were suggestive of air *On the morning following* admission the loud crackling sound over the precordium had entirely disappeared The patient had not been aware of the noise in his chest *The pain had entirely disappeared and the patient wanted to go home* The following morning however the pulse was entirely irregular and the electrocardiogram showed auricular fibrillation Within several hours the rhythm became normal and remained so There was no electrocardio graphic evidence of coronary occlusion

Diagnosis Spontaneous mediastinal emphysema Hamman[26] has recently described this condition which has doubtless been confused with true cardiac disease particularly coronary occlusion The syndrome is caused by the release of air into the tissues of the mediastinum The heart itself is normal

6 X RAY MEASUREMENT OF HEART

It is not necessary to go into details or technic of this method of arriv ing at the size of the heart except to say that measurements of the normal hearts that are to be discussed are derived from either teleroentgeno grams or orthodiagrams They indicate therefore the actual size of the heart as it functions

In attempting to decide whether or not a heart is of normal size it is well that the examiner bear in mind certain peculiarities of the normal heart For example the right auricle according to Hamilton[11] under goes rapid hypertrophy during the first six weeks of life allowance for *this natural phenomenon must be made before diagnosis of auricular* hypertrophy is made

Lincoln and Spillman have published a very interesting study of the child s heart derived from yearly x rays of 216 normal school children during seven school years They found that the average median diameter of the right side of the heart increases steadily with age in children from 2 through 13 years of age being greater in girls than in boys Before the age of seven the girl s heart is larger than the boy s after the age of 11 the condition is reversed The transverse width of the heart varies between 7 and 8 2 per cent of the height of boys from 2 through 13 years of age and from 6 9 to 8 1 per cent of the height of girls of corre sponding ages There was found to exist a closer correlation between the size of the heart and height than between the size of the heart and age Approximately one third of the heart lies to the right of the midline in

$$\frac{\text{Transverse heart measurement}}{\text{Transverse lung measurement}}=\frac{1}{1.9}\text{ in children}$$

$$\frac{\text{Transverse heart measurement}}{\text{Transverse lung measurement}}=\frac{1}{1.92}\text{ in 20-year-old subjects}$$

$$\frac{\text{Transverse heart measurement}}{\text{Transverse lung measurement}}=\frac{1}{1.95}\text{ in 30-year-old subjects}$$

The figure for the normal heart may be as high as 1:1.99. Chest measurements were made from the ribs.

East and Bain[7] agree that the width of the heart, as a general rule, *should not be greater than one half that of the chest*, but find in the literature evidence for a certain latitude in applying the rule. Certain roentgenologists feel that the normal heart may measure as much as 55 per cent of the width of the chest in individuals of peculiar body configuration.

Moritz[19] prefers orthodiagraphy of the heart, especially with the patient horizontal, to teleroentgenography, as he feels that the cardio-hepatic angles particularly can be examined best by horizontal orthodiagraphy. He considers, however, that both methods should be employed. Moritz further believes that planimetric examination of the heart's shadow is to be preferred to simple transverse measurements. He proposes a "heart rectangle" method. After obtaining this measurement *he compares it with standard body measurements obtained from height*, weight, and ideal body weight expressed by Bornhardt's unit.

The actual size of the adult heart, at least as far as can be estimated from a large number of measurements upon the hearts of normal soldiers, has been shown by Smith[23] to be as follows:

Height Cm	*Cases*	*M R Cm*	*M L Cm*	*L D Cm*	*B D Cm*	*Area Sq Cm*
155 to 164	18	4 0	8 3	13 3	9 9	111
165 to 174	174	4 1	8 5	13 1	10 2	118
175 to 187	185	4.3	8 7	14 2	10 7	122

M L. Distance from the midline to the most distant left border.
M R. Distance from the midline to the most distant right border.
L D. The maximum long diameter measured from the right auricular notch to the *most distant apical border*.
B D. The maximum broad diameter measured at right angles from the long diameter to the most distant border above and below.

7. CARDIAC OUTPUT

For a general review of the principles and methods of cardiac output determinations, a lecture by Marshall[18] may be referred to. He holds the opinion that the problem of cardiac output is not yet solved in a quantitative sense, but that great advances have been made. Three general methods have been used (1) Methods based upon the principle of Fick; (2) methods based upon the rate of absorption of some foreign gas through the lungs; (3) measurements by x rays of the systolic and diastolic shadows of the heart and deductions therefrom

A popular method is that based upon the absorption rate of a foreign gas; according to Marshall, there is close agreement among the results from human beings whether ethylene, nitrous oxide or acetylene is used as the foreign gas Ethyl iodide seems to give satisfactory results, while carbon dioxide results are open to some question.

The Fick principle involves the use of the triple extrapolation method Different known mixtures of nitrogen, carbon dioxide and oxygen are rebreathed by the subject, and the cardiac output is calculated from determinations of oxygen and carbon dioxide tensions of the arterial and mixed venous blood Though Kroetz[13] considers that the Fick principle is practicable only in animals, in which the jugular vein can be entered with a cannula, Grollman[9] has found a close correlation between results obtained from the use of this and of the foreign gas methods Grollman believes that the condition of the subject is of more importance in the measurement of cardiac output than is the method provided the method be employed skillfully

Cardiac output was determined by the acetylene method in 59 normal young individuals and found to be 2 18 liters per minute per square meter of body surface A normal male subject examined at home under strictly basal conditions showed a very constant cardiac output throughout 1½ years, the total cardiac output was found to be 3 9 liters per minute, varying on different determinations not more than ± 0 2 liter A female subject showed somewhat more variation at different times, but not more than ± 10 per cent Kroetz, also using the acetylene method, reports the cardiac output, with subjects sitting, to be 3 55 liters per minute or 1 96 liters per square meter of body surface per minute.

The average stroke volume in normal individuals has been estimated by Stewart, *et al*, as 57 cc[27] The same authors report that the cardiac

index (Cardiac Output in liters per square meter of body surface per minute) in normal individuals is 2 11 while Grollman [8] puts the range between 1 90 and 2 19

Planimetric estimations of the size of the heart in systole and in diastole permit the deduction that the difference in size of the heart in those phases is quantitatively related to the amount of blood expelled (from both sides of the heart) with each beat The figure thus obtained is 1 9 cc per kg of body weight per beat or 0 9 cc from the left ventricle This figure is similar to that obtained by gasometric methods

The volume of blood passing through the heart is approximately the same as the volume of air inspired when the subject is at rest On exertion the ventilation of the lungs increases out of proportion to the increase in circulatory flow

Both Marshall and Grollman[10] emphasize the necessity of strictly basal conditions for proper study of the cardiac output per minute Marshall points out that there is no significant difference in the volume of the single cardiac output whether the subject is recumbent sitting or erect However due to the increase of metabolism when the subject is erect the rate of circulation is accelerated by the increase in heartbeats per minute rather than by augmentation of the volume of cardiac output per beat

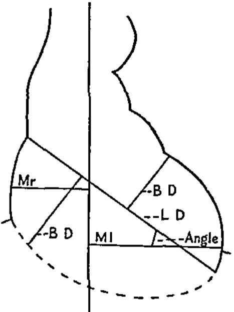
8 CIRCULATORY RATE (Determination)

There is considerable interest in studies of the natural and pathological circulatory rates in man For purposes of this determination Blumgart and Yens[3] developed a method based upon the injection intravenously of the active deposit of *radium* upon table salt in one arm and the measurement of the appearance time of the radium deposit in the arteries of the opposite arm A detecting device consisting of a chamber *containing water vapor in a state of critical supersaturation shows the* presence of radium deposit in the arteries of the second arm through the condensation of vapor along the ionized path produced by the two rays The path is illuminated and is shown by a white streak

Advantages of this method lie in the fact that radium in the amount used (1 to 6 millicuries) is nontoxic and that it has no effect on blood pressure or on cardiac rate or rhythm The test is done with the subject in the basal condition The time involved in the passage of radium from the veins of one arm to the arteries of the other has been found to be

14 to 24 seconds the average time in normal subjects between 15 and 75 years of age being 18 seconds The method has been found of considerable value in showing the retardation of the circulatory rate in various pathological conditions

Lian and Barras[15 16] have discussed various methods of determining circulatory rate, such as the injection of *potassium ferrocyanide* into the jugular vein and its time of appearance in the other jugular, and the



(1) *Ml* Maximum left border (2) *Mr* Maximum right border (from the sum of these was obtained the maximum transverse diameter T D) (3) *L D* Maximum long diameter from the right auricular notch to the most distant apical border (4) *B D* Maximum broad diameter measured at right angles from *L D* to most distant borders (5) Angle formed by long and transverse diameters (6) Diameter of aortic arch. (7) Parallel ray silhouette area was obtained by the planimetric method and from this was calculated the volume by the Bardeen formula (Smith Arch Int Med)

method that utilizes the injection of *methemoglobin* These workers prefer the *fluorescein* method 2 cc of a 5 per cent solution of fluorescein is injected intravenously at regular intervals thereafter venous blood from the opposite arm is collected into small tubes containing 95 per cent alcohol In subjects free of cardiac trouble the dye appeared 30 seconds after injection, usually reaching its maximum intensity between one and two minutes after injection The dye diminishes in amount after two minutes and usually fails to appear after the end of the third minute In 25 patients with cardiac disorder the dye failed to appear before the normal time of 30 seconds

A simple method consists of the injection of 5 cc of a 20 per cent solution of *sodium dehydrocholate (decholin)* intravenously and determination of the time that elapses between injection and the development of a bitter taste in the mouth of the subject Injection should be made without preliminary vascular constriction The venous to arterial circulation by this method has been estimated for normal subjects at 8 to 14 seconds (Winternitz[20]) and 10 to 16 seconds [29] A variety of other tests have been devised to estimate the rate of circulatory flow [20] On the whole the Decholin Method is probably open to less objections than many of the others The circulation is not significantly accelerated by tachycardia until the rate exceeds 140 per minute nor slowed unless the rate is less than 45

Using 3 cc of a 20 per cent solution thus shortening the injection time Gargill[2] found the arm to tongue circulation time in normal persons to be 15 to 20 seconds from the beginning of the injection allowing three seconds for injection the average actual circulation time was 13 seconds The bitter taste disappeared in 15 to 25 seconds a repeated determination as a check is desirable

This is not the place for a detailed description of normal and abnormal electrocardiograms however tracings obtained from normal hearts are not infrequently misinterpreted as abnormal tracings In the writer's experience the commonest cause of error is digitalis Outside a certain prolongation of the auriculoventricular conduction time which may or may not be found in the tracing of a normal heart under the influence of digitalis there occur quite regularly changes in the S T portion of the tracing These changes constitute the most delicate criteria of the effect of digitalis on the heart The commonest effect is a depression of the S T interval from the isoelectric line the depression is similar to a lateral view of a foot pedal the proximal or S end of the period remaining relatively fixed while the terminal end is most markedly depressed carrying the first part of the T wave with it The T wave may thus become diphasic flattened or actually inverted but it does not acquire the appearance which is found in certain cases of frank coronary disease in which the T wave has the appearance of a fishhook with an upward convexity In digitalis effect a curving of the S T interval is very common but this consists of an upward concavity and downward convexity This is one of the most characteristic digitalis effects The foot pedal type

of depression described above may be simulated so closely by coronary disease and perhaps by cardiac strain as to make it impossible to recognize the causative agent

It should also be remembered that heavy consumers of alcohol whether their diet is defective or not may show flattening or actual inversion of the T waves of any one or all the leads Smoking may cause a slight depression of the takeoff of the S T interval Some observers report changes in the T waves from drinking iced beverages All such causes of changes in T waves are usually temporary and the changes themselves reversible Similar effects are common in infectious diseases but it is doubtful whether the heart could be considered strictly normal under such circumstances

Electrocardiograms of apparently healthy individuals show a variety of changes that are difficult to interpret since in the absence of a pathological examination it is impossible to determine whether the heart is structurally normal or not Inversion of the T waves in Lead III is of no significance but if the inversion extends to either or both of the first two leads the tracing must be considered definitely abnormal although such changes are not infrequently reversible A deviation of the S T interval from the isoelectric line may also be present to a slight degree in Lead III and yet have no significance A deviation of this interval above or below the isoelectric line in either or both of the first two leads is abnormal although it may be reversible (v s) An elevation of the S T interval in the standard chest lead IV F apparently occurs in almost half of normal individuals and may be considered of no significance A frank inversion of the T wave in Lead IV F is usually abnormal although the writer has seen apparently healthy children that showed a diphasic T IV F

Finally predominance of the levogram should not be taken too seriously In many instances simple predominance of the levogram occurs in healthy individuals in middle or late life apparently as a result of changes in body habitus particularly in such cases in which the diaphragm becomes elevated and the heart assumes a more transverse position

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CHAPTER XXV

THE CARDIAC PATIENT AS A SURGICAL OR OBSTETRICAL RISK

By Samuel A Levine M D F A C P

SURGICAL CONSIDERATIONS

Physicians are frequently asked by their surgical brethren or by their patients whether the heart can stand a contemplated operation This question is by no means as simple as it sounds and like the one put to a man on the witness stand when he was asked if he would stop beating his wife it cannot be answered categorically yes or no It places on the physician a triple responsibility First he must aid in the underlying diagnosis for often a condition that is regarded as surgical may in fact be due to a disorder of the heart itself or to the peripheral circulation for which medical treatment would be indicated The second aspect of this problem is to ascertain if possible the prognosis of the cardiac condition that is present in order to aid in advising whether a surgical operation that ordinarily would be indicated and justifiable should be undertaken It is obvious that if a patient has advanced hypertensive heart failure he should not be subjected to an operation such as repair of an abdominal hernia This requires the intelligent appraisal of the cardiac state and an attempt to foretell how long a patient may be expected to enjoy the benefits of the surgery that is planned Finally when an operation is decided upon in one suffering from some form of heart disease the physician may aid in estimating with what added risk a particular cardiac abnormality is attended and in what way the risk might be minimized The above questions therefore entail a close cooperation between the surgeon and physician permitting a free and detailed analysis of all the factors concerned

Differential Diagnosis Let us first consider some of the difficulties that arise in differential diagnosis in distinguishing what appears to be an acute surgical abdominal condition from disorders that are produced

directly by the heart or cardiovascular system In former years it was not an infrequent experience to confuse acute coronary thrombosis and myocardial infarction *with acute abdominal emergencies such as perforated* peptic ulcer acute pancreatitis acute disease of the gallbladder diaphragmatic hernia, acute intestinal obstruction etc There is hardly any active surgical clinic that has not made the error of exploring the abdomen when the cause of the epigastric pain vomiting and collapse was a thrombosis of the coronary artery This confusion was discussed many years ago[1] since which time much has been learned to help us avoid similar blunders In fact our knowledge concerning diagnosis of coronary artery disease has become so extensive that at present there is possibly greater danger of overlooking abdominal conditions that require immediate operation when this type of differential diagnosis arises

There are certain precautions that may help in this decision Realizing that severe epigastric distress or pain may be due to disease of the heart or of the abdominal organs a previous history of angina which often has to be deliberately inquired for lends some support to the former as the cause in any particular case Pain from coronary artery disease even when localized in the abdomen tends to radiate up the sternum or to the *arms and almost never extends below the umbilicus It is also often asso*ciated with dyspnea *One should always suspect the abdomen when the differential problem arises in a woman if it is known that the patient was not hypertensive* This general rule does not apply in the male sex

Finally the electrocardiogram which now can be taken so readily at the bedside may give invaluable information Although there may be pathognomonic changes pointing to myocardial infarction great caution needs to be exercised in reading too much into less distinctive alterations in the form of the ventricular complex There will be instances that tax all our diagnostic resources including x ray plates of the abdomen looking for free gas below the diaphragm It is needless to go into a complete discussion of all the conditions that may arise for they are numerous Suffice it to recall that many of the common acute abdominal conditions may be confused with an attack of atypical coronary thrombosis

Similarly *there are occasional instances when the acute development* of congestive heart failure can present the picture of an acute surgical condition of the abdomen This is apt to occur with the sudden onset of auricular fibrillation especially in a previously undigitalized heart If

mitral stenosis is present, and it may not have been recognized or easily detectable, acute pain and spasm in the epigastrium or right upper quadrant, slight fever and leukocytosis, nausea, vomiting and even slight jaundice may result. The presenting findings in such cases probably are the result of acute congestion of the liver with stretching of its capsule and may be misjudged as due to acute cholecystitis. The therapeutic decision is not very difficult as *ordinarily there is no great haste about surgery* for disease of the gallbladder, and the presence of a rapid irregular heart rate in any case deserves digitalis therapy and other treatment for heart failure, if evidence of congestion is found. When the above symptoms are due to the heart they will promptly be relieved by appropriate cardiac therapy.

In younger patients acute pain in the abdomen, resembling that due to acute appendicitis, may occur in rheumatic fever. The pain need not be very severe but can be accompanied by nausea, some localized tenderness and vomiting, slight fever and leukocytosis and in many ways imitate very closely what is found in acute appendicitis At times it will be impossible to distinguish the two conditions with any certainty and an exploratory operation will be necessary and should be regarded as the correct procedure even if it turns out to have been unnecessary

Some of these operations will be unavoidable for *there is greater risk in delay when the appendix is inflamed than in an abdominal exploration when mild rheumatic fever is present.* There are times, however, when careful attention to details will reward the physician by enabling him to make a more definite diagnosis Rectal tenderness is much more apt to indicate appendicitis, as it is quite rare in rheumatic fever.

Of greater importance in these cases of atypical rheumatic fever with abdominal symptoms but without pains in the limbs, are the direct findings in the heart. One may detect distinct abnormalities in the heart that occur with particular frequency in rheumatism and are rare in other conditions. The finding of a loud systolic murmur or a diastolic murmur that was not previously present, a pericardial friction rub, or the detection of delayed A-V conduction time (increased P R interval in the electrocardiogram) would make the diagnosis of rheumatic fever fairly certain. I recall an instance in which the surgeon heard a peculiar sound over the precordium which he was unable to interpret This proved to be a gallop rhythm which in children should always make the physician suspect a delayed P R interval (or first degree heart block). This turned out to be

the case and the young girl recovered on salicylates thereby avoiding what might have been an ill advised operation

Other medical conditions that may present themselves with what appears to be an acute surgical abdomen are pneumonia and acute pericarditis These acute inflammatory *processes in the thorax especially when* they occur in childhood may first manifest themselves with abdominal pain and vomiting Only the scrupulous care of a thorough physical examination and the constant recollections of these possibilities in differential diagnosis will prevent the confusion that otherwise will take place Similarly the rare cases of tabetic crises lead colic and other nonsurgical conditions must be sought for when the cause of abdominal symptoms is being investigated

Significance of Symptoms In appraising the significance of abdominal or other symptoms that appear to have surgical implications the possibility *of embolism must not be forgotten One should have this partic*ularly in mind under the following four conditions Auricular fibrillation mitral stenosis coronary thrombosis with myocardial infarction and bacterial endocarditis With the first two sterile thrombi form in the auricles with the third in the ventricles and with the last infected vegetations are *present on the valves If parts of these thrombi become dislodged em*bolism develops When such emboli involve the renal splenic or mesenteric arteries abdominal symptoms result Careful examination of the cardiac state will prevent the physician at least from overlooking these nonsurgical causes of abdominal symptoms

Prognosis versus Surgical Risk *The second aspect of this problem* is whether the prognosis of the cardiovascular state is good enough to warrant the contemplated surgical operation Is the patient with a particular type of heart disease going to live long enough to enjoy the results of the surgery? This is entirely a matter of prognosis and here judgment *is difficult* Those operations which in themselves help the embarrassed circulation are always better borne and will be more beneficial in their end results than when there is no direct relation between the surgical and cardiac conditions A patient with mitral stenosis auricular fibrillation and hyperthyroidism in advanced congestive failure for example will actually show marked improvement in the heart following a subtotal thyroidectomy It would be unwise in such a case on the other hand to advise an operation for repair of a cystocele In patients with angina pec

tors occasionally the cardiac state seems to be improved following the removal of gallstones or after the relief of prostatic obstruction. Apart from the cases in which the heart itself may be more or less improved by the operation, great care must be exercised in not advising major surgical procedures for those conditions which are not urgent or for which there are available adequate nonsurgical or palliative measures. When one would judge the life expectancy of a given cardiac disease as one to two years, it is illogical to advise a hysterectomy for fibroid tumors of the uterus when x-ray treatment may control the menorrhagia. If a patient has had hypertensive heart failure and shows a bundle branch block or gallop rhythm or pulsus alternans it is better to temporize with a truss than to operate for an ordinary inguinal hernia. Removal of teeth and tonsils and procedures such as pelvic operations for prolapse of the uterus or a relaxed pelvic floor may be avoided when contemplated in those suffering from grave heart disease. An illustration of such a problem is the following experience.

> A woman aged 40 complained of lower abdominal discomfort and excessive uterine bleeding. She had luetic aortitis and aortic insufficiency. She also showed evidence of a large uterine fibroid which could barely be felt above the pubis. A hysterectomy had been advised by another physician. Because of her cardiac condition it seemed wiser to try x-ray treatment. This was carried out and caused cessation of her menstrual periods and the tumor could no longer be felt. A simple method without risk achieved the same therapeutic result as the contemplated surgery.

In all these matters the intelligence of the physician must be used weighing all the circumstances pertaining to the prognosis of the type of heart disease that is present and *the amount of discomfort and hazard* from the surgical conditions.

Estimation of Surgical Risk. The final phase of this problem is the estimation of the risk that a patient with heart disease undergoes in a major surgical operation. *There has been altogether too much fear concerning the ability of the heart to withstand operations.* When postoperative deaths have occurred physicians have been too prone to ascribe the cause to the heart. In all fatal cases death occurs when the heart stops but that is by no means synonymous with death from heart failure or heart disease. On close scrutiny it will be found that in only a few in

stances can the heart be blamed as playing even a contributing rôle in the cause of the fatality

Let us first consider what changes take place in the heart during an operation Marvin and Pastor[2] found that there was no constant change in the blood pressure during or following operations In some the pressure rose and in others it fell They decided that the only instances in which the change in pressure materially affected the incidence of untoward complications were those in which there was extreme lowering of the blood pressure and pulse pressure with a state of shock It was also found[3] that routine preoperative administration of digitalis failed to exert a favorable influence on the blood pressure or on the incidence of postoperative complications In fact there was suggestive evidence that digitalis may have a slightly deleterious effect On the other hand Blalock[4] found that the average output of the dog s heart during ether administration was increased 76 per cent In this experimental investigation it was also found [5, 6] that the increase in the cardiac output could be diminished by the use of alkali or digitalis From these experiments it would seem that the work of the heart might be temporarily increased during surgical operations However, in actual surgical cases Snyder[7] found an average decrease of 41 per cent in cardiac output directly after operations while the patients were still under the anesthetic and that it required one to four days for the output to return to normal How material these various effects might be in the operative risk can only be ascertained by clinical experience

Brow and Long have shown[8] that chloroform ether nitrous oxide and barbiturate derivatives when used to produce anesthesia in cats cause a decrease in glycogen storage and an accumulation of acid metabolites (lactic and phosphoric acid) in cardiac muscle Furthermore disturbances in the mechanism of the heartbeat have been observed during anesthesia Levy[9, 10] noted in cats the development of extra ventricular systoles ventricular tachycardia and ventricular fibrillation at certain low concentrations of chloroform anesthesia He thereby explained the mechanism of sudden death which occurred under chloroform In routine operations on surgical patients during anesthesia produced by ether, nitrous oxide or procain Lennox Graves and Levine[11] observed frequent abnormalities of the heartbeat such as premature beats dislocation of the pacemaker especially resulting in nodal rhythm and even paroxysmal auricular

tachycardia These were found to be transient and with very rare exception were of physiological rather than clinical interest Only on rare occasions did the development of a new rhythm during an operation produce alarming symptoms A study of such disturbances[12] has shown that they are due to paroxysms of auricular tachycardia auricular fibrillation or auricular flutter When properly recognized they are easily controlled by carotid sinus or ocular pressure or by the use of such drugs as mecholyl digitalis or quinidine Despite the above physiological and chemical alterations which take place during anesthesia and operations how much harm they produce can only be determined by studying the incidence of postoperative complications and fatalities in cardiacs and noncardiacs This is the only method available to determine the surgical risk of various types of heart disease

Extensive experience during the past two decades has afforded adequate proof that patients with heart disease on the whole withstand surgical operations very well The old fears concerning the heart, although they still persist in the minds of the laity and to a slight extent of the medical profession have largely disappeared A review of over 100 patients[13] suffering from organic heart disease who were subjected to various major surgical operations showed that the unexpected mortality was only 6 ½ per cent Furthermore on investigating the cause of postoperative death in cardiacs it becomes evident that death results for the most part from the same complications that occur in noncardiacs[14] *i e*, postoperative pulmonary complications shock infection etc True cardiac failure is rare although some of the so-called accidents of heart disease such as coronary thrombosis and pulmonary and peripheral embolism do occur more frequently

In estimating the risk which a given cardiac condition adds to that of the contemplated operation there are two important factors to be considered The first and by far the most important is the ability of the heart to respond to effort If the cardiac condition has been well compensated if the patient has been able to carry on his ordinary duties the heart has already given evidence of withstanding a greater load than any operation will demand This has reference to the heart and not to the peripheral circulation for the latter may fail with equal facility whether the heart is diseased or not

It follows therefore that the history pertaining to cardiac efficiency is much more important than the physical examination of the heart The presence or absence of breathlessness is much more informing than whether a murmur or some cardiac hypertrophy is present The second important factor is the liability of that particular heart to the so-called accidents of heart disease These are the unpredictable complications that occur which suddenly change the entire status and prognosis of the situation Amongst the latter are the development of acute coronary thrombosis embolism sudden changes in cardiac rhythm such as Adams Stokes attacks or paroxysmal rapid heart action bacterial endocarditis and sudden death possibly due to ventricular fibrillation Fortunately such postoperative complications are not very common though they do occur One can classify cases into those that are more and those that are less likely to develop these complications but it is impossible to fore tell events in individual instances

Because it is mainly the above accidents of heart disease that increase the operative risk of cardiac patients it is of some interest to analyze the circumstances under which they may arise Coronary throm bosis can occur in anyone suffering from coronary artery sclerosis The main clinical evidence of this will be the history of angina pectoris Therefore it becomes extremely important to inquire most carefully into those symptoms that characterize the anginal state Often when a postoperative coronary attack has occurred apparently in one who was regarded as previously having a normal heart it later becomes evident on close scrutiny that there was a definite history of sternal constriction on effort which had been entirely overlooked Even some sudden and instant postoperative fatalities will prove to have a similar explanation

Embolism from the heart mainly comes from sterile mural thrombi from the auricles in cases of auricular fibrillation or of mitral stenosis and much more rarely from the ventricles in cases of myocardial infarc tion The presence of these conditions therefore predispose to such complications Complete heart block obviously is the most common condition in which sudden Adams Stokes attacks may occur but the various types of paroxysmal rapid heart action may develop in patients with otherwise normal hearts although more frequently in those with organic heart disease Postoperative bacterial endocarditis is very rare but may develop in one who previously gave evidence of a well com

pensated, regular heart and in whom there was some kind of cardiac murmur Such disastrous complications have been observed particularly after tonsillectomy or extraction of teeth possibly because these simple operations are so common

Notwithstanding the various hazards to which patients with heart disease are subject on the whole, the operative risk is rather small An operative mortality of 2 1 per cent in 147 cases of valvular disease and of 3 0 per cent in 103 cases of auricular fibrillation[13] indicates how satisfactorily cardiacs tolerate major surgical procedures The risk increases, however, under certain circumstances Cases of angina pectoris for the most part occurring in the second half of life, carry a risk of 7 7 per cent This is mainly due to the postoperative development of coronary thrombosis, a subject recently emphasized by Master and associates[15] The danger is still greater amongst those who have already suffered a previous attack of coronary thrombosis The proper timing of operations and selection of cases should even here keep the rate about 15 to 20 per cent The presence of congestive heart failure adds decidedly to the risk of operation but except for emergencies adequate preoperative medical treatment will decidedly reduce this risk Although hypertension has little effect on the mortality rate the presence of chronic nephritis increases it threefold In general it may be said that *all cardiacs do surprisingly well except for those who have nephritis, congestive failure or coronary artery disease*

So far no mention has been made about the type of anesthesia in its relation to the operative risk in cardiac patients There has been no extensive analysis of the relative merits of different anesthetics for those suffering from organic heart disease Our opinions, therefore, rest upon general impressions rather than convincing data Differences in point of view amongst different observers probably signify that the matter is not of great importance Marvin[16] very wisely stated that it is far more important to select the proper anesthetist than it is to select the proper anesthetic The choice will generally be determined after a consultation between surgeon anesthetist and physician with the goal that a smooth, shockless anesthesia may be obtained Ether, avertin, ethylene, spinal and local anesthesia each have their advocates The important factors that seem to be material are to avoid struggling, the collection of mucus in the upper respiratory tract and cyanosis and to prevent a maintained fall in blood pressure The disadvantages of the former are obvious and

there is reason to believe that a significant fall in blood pressure, apart from being a forerunner of surgical shock, is conducive to the development of coronary thrombosis. It is for this latter reason that when spinal anesthesia is used in elderly patients who often have coronary artery sclerosis great care should be taken to prevent any untoward fall in the pressure level. *In general, I prefer ether anesthesia in cardiac patients,* although there are reasonable differences in views amongst *reputable authorities.*

In conclusion, it may be stated that intelligent cooperation between physician, surgeon and anesthetist will enable most patients suffering from heart disease to undergo surgical operations with only slightly greater risks than prevails in noncardiacs. It will also avoid ill-advised operations on cases that present features resembling surgical conditions which in point of fact are due to some form of cardiovascular or nonsurgical disease. By proper preoperative care and timing of the operation when possible, it will diminish the surgical risk. Finally, careful diagnosis and prognosis will eliminate many unwise operations for which palliative nonoperative measures are available when the patient might not be expected to live long enough to enjoy the results of the surgery.

OBSTETRICAL CONSIDERATIONS

The problem of the cardiac patient and pregnancy has many ramifications. The physician has to consider not only the purely medical aspects of the case but also religious, social and economic factors. Decisions will therefore have to differ even when the physical condition of the heart may be the same, depending on these other factors. The whole problem is one in which the medical profession has made considerable progress. The application of modern methods of diagnosis and treatment of heart disease and the institution of a systematic control of cardiacs who may become pregnant has decreased the maternal mortality amongst organic cardiacs during the past ten years from about 20 per cent to about 3 per cent.[17] By the proper selection of patients who should become pregnant and the intelligent care during pregnancy, many lives are now being saved that were previously sacrificed.

Effect of Pregnancy on Normal Heart. Let us first consider the effect of pregnancy on the normal heart. Studies of the dynamics of the circulation[18, 19, 20] have shown that there is a decided gradual increase

remainder of the pregnancy. Even when treatment results in restoration of compensation, activities should be restricted to a bed and chair existence with very little more until after the delivery.

The advice given to cardiacs will differ materially depending upon the number of children there are already. In the absence of decompensation or other evidence of grave heart disease all cardiacs should be allowed to go through their first pregnancy. In fact, they should be urged to have their baby soon. The heart does not get better with increasing years and the mother will live longer to enjoy the life with the child than if pregnancy is delayed. Furthermore, when a normal viable child has been obtained without any difficulties, it is wise to advise such a patient to have a second child within the next two years. Most parents want more than one child and it is better to make the final decision about this matter immediately than to have it come up five years later. The question of a third child, providing that compensation has remained satisfactory, is entirely optional with the parents. When there are already three normal children there is good reason to advise cardiac mothers to avoid any further pregnancies. Although there are numerous instances of women with mitral stenosis surviving six, eight or ten pregnancies, there are a good many others who have succumbed. Under the best circumstances the risk is greater than normal for any cardiac who belongs to group three. There is therefore, a definite indication for the use of contraceptives in all cases of organic heart disease when there are already three children or for performing abortion if pregnancy has already occurred. *There is very little evidence to show that cardiacs going through pregnancies without failure of the circulation shorten their lives.* Reid[21] showed that married women suffering from heart disease who had borne on the average more than five children died at an average age only slightly less than unmarried cardiacs. In all these considerations due attention must be paid to the wishes of the parents, their religious restrictions and the economic and social status of the household, bearing in mind that the actual bringing up of several children is a considerable task on a diseased heart.

Sterilization should never be performed unless it is absolutely certain that no more pregnancies are to be permitted. It is generally unwise to perform sterilization at the time of the first pregnancy, for the child may not survive the first few days or may be an abnormal child. On

several occasions I have seen well compensated cardiacs who had a cesarean section at the time of their first pregnancy and had their tubes tied, who lost their babies during the first 24 hours They were in a sufficiently good state of compensation readily to have gone through subsequent pregnancies, but had to remain childless the rest of their lives Furthermore a cesarean operation should not be advised merely to enable the obstetrician to sterilize the patient This should be done at a later time if advisable Notwithstanding the fact that there is some difference of opinion amongst obstetricians I favor the opinion that the procedure of choice is delivery by the pelvic route unless there are obstetrical indications for an abdominal section The second stage of labor should be abbreviated by the use of low forceps The type of anesthesia is not of great importance although cardiacs in general do well with ether If an abdominal operation is decided upon and there is or has been cardiac failure or a sufficient number of children have already been born, sterilization should be performed at the same time

It is obvious that women who are in congestive failure should not become pregnant and should be aborted during the first two or three months of pregnancy But if they are first seen in gross failure after the fifth month or develop failure in the latter months of pregnancy most painstaking cardiac treatment should be carried out to reestablish adequate compensation or at least to carry the mother far enough to obtain a viable child To avoid the development of congestive phenomena in those suffering from major cardiac disease the salt and fluid intake should be restricted but protein should be given liberally and iron as well if necessary Hypoproteinemia and anemia are potential factors that may further embarrass the circulation and often can be readily prevented

The value of carefully classifying cases according to diagnosis and functional capacity is well brought out by the statistics compiled by Pardee[22] He reported no deaths amongst 157 organic cardiacs who showed no evidence of failure on considerable effort one death in 180 patients with only slightly restricted activities 8 out of 169 who were greatly limited in their response to effort and 16 out of 30 who were essentially bedridden The results published by Fitzgerald[23] and Hamilton and his collaborators[17-4] are all in accord with these results Despite these excellent results unexpected and unpredictable disasters can occur

At times congestive failure develops even in the form of acute pulmonary edema when everything pointed to a favorable course The latter may require morphia and even phlebotomy and oxygen therapy Rarely subacute bacterial endocarditis proves to be a fatal complication of what would otherwise have been a minor infection These complications apart from those to which normal pregnant women are subject are responsible for the small but irreducible mortality of pregnancy in cardiacs

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CHAPTER XXVI

HEART SOUNDS

By Charles C. Wolferth, M.D., and Alexander Margolies, M.D.

Introduction. In the consideration of sound it is necessary to bear *in mind that there are two components involved, viz., the actual vibrations* and the sensation produced by these vibrations. Students of sound may be interested primarily in either or both. When the clinician practices cardiac auscultation he is concerned with the auditory sensations produced by the vibrations. If, on the other hand, he registers the sounds by means of a sound recording apparatus, he interests himself in the physical characteristics of the vibrations. In the use of terminology it is necessary to bear these distinctions in mind. Thus, intensity and loudness of a sound are not interchangeable terms, although, as intensity *increases or decreases, loudness varies in the corresponding direction.* The human auditory apparatus has so accommodated itself to its environment that tremendous changes in intensity may be reflected by what seem to be much less marked changes in loudness. Furthermore, the *sensation of loudness of a sound may be modified by stimuli immediately* preceding it. Thus recorded vibrations do not faithfully mirror what is heard on auscultation.

The knowledge concerning heart sounds which had accumulated *from the time of Laennec until 1907, when Einthoven published his* string galvanometer method of registering sounds, was based almost entirely on auscultatory studies, since previous attempts at registration had not been very successful. The literature covering the period during *which this knowledge was in the making reveals much inaccurate observation* and reasoning responsible for certain misconceptions still widely held today. On the other hand, the work of some of the great masters of auscultation, notably Potain, must command our admiration.

Sound registration has made possible accurate study of the time relations of heart sounds with other cardiac events, thus furnishing data

essential for the understanding of the mechanism of production of the sounds. Attempts have also been made to study the physical characteristics of the vibrations, but because of the imperfections of the methods of registration available, great caution must be observed to avoid error. In spite of these limitations, Einthoven,[1] Lewis,[2] Wiggers,[3] and others have been able to make notable contributions to the understanding of heart sounds

Most of the important heart sound registration studies have been made by physiologists who were not primarily interested in the clinical applications of the method, although many facts of clinical importance have been demonstrated There remain wide gaps in our knowledge regarding the mechanisms of sounds produced by cardiac action in normal and diseased hearts. This discussion is an attempt to bring the student and the practitioner abreast with current knowledge of the subject.

The unsatisfactory state of the art of auscultation as it is generally practiced becomes obvious to anyone in a position to review the findings of various examiners of the same patients and the differences in the conclusions reached following such examinations. Nevertheless, it may be stated that nearly all these differences of opinion are unnecessary and due to the fact that many physicians have not rigorously trained themselves in the art of auscultation. To acquire this training, no superiority of senses is needed. Reasonably normal ability to concentrate, normal hearing, a normal sense of timing and a normal appreciation of such qualities of sound as pitch and loudness are about all the qualifications that are necessary. Most medical students and practitioners possess all of them Many errors in auscultation are those of omission, due to such factors as lack of thoroughness of examination or unfamiliarity with certain types of sounds Most students are apt to miss the low-pitched murmur of mitral stenosis until their attention has been called to this sound and they have become thoroughly familiar with its characteristics As soon as their receptor mechanisms are trained, they develop proficiency in the recognition of the murmur. Today, perhaps only a small minority of even well trained physicians recognize with any approach to accuracy such a common and important auscultatory finding as gallop rhythm. Nevertheless, gallop rhythm is nearly always easy to detect after one has become familiar with it The important steps in acquiring skill in the

art of auscultation are (1) to acquire familiarity with the various sounds and murmurs and their characteristics; (2) where to listen for them; (3) what maneuvers may be employed to elicit or accentuate sounds and murmurs, and (4) to educate one's sense of timing. One of the most frequent errors of interpretation of sounds is due to faulty timing.

What value sound registration may possess for further clinical research would be difficult to predict. There is one field, however, in which sound registration studies have a real value. Their comparison with auscultatory findings constitutes an excellent training method for sharpening the auscultatory faculty. Recently there has been a great reawakening of interest on the part of clinicians in the study of heart sounds, doubtless due in part to improvements in methods of registration.

THE FIRST HEART SOUND

It has been established that the first heart sound is related to an early stage of ventricular contraction. Einthoven[4] believed that the sound and electrical disturbance in the ventricle begin simultaneously. Wiggers,[5] however failed to confirm Einthoven's observation and believes that the beginning of the electrical disturbance precedes the sound.

The assumption is generally made that the first sound heard over the precordium is almost wholly left ventricular in origin, but studies of *asynchronous contraction and splitting of the sounds, such as occur in* ventricular extrasystoles and bundle branch block, suggest that the right ventricle sometimes contributes a larger share than is generally believed.[6] Although the right ventricle usually contains much less muscle than the left and by reason of lower pressure probably does not contract so forcibly, nevertheless, the position of the heart is such that sounds produced in the *right chamber may be better transmitted through the anterior chest wall* than those from the left side.

It is assumed by many writers that mitral and tricuspid valve closure are concerned in the sound production and it is customary to designate certain comparatively short high-pitched first sounds as having a "valvular quality." It is probable that the valves close early in systole while intraventricular tension is still low. There is at present no convincing evidence to indicate whether or not valve closure contributes vibrations to the first sound. The practice, therefore, of describing certain first sounds as "valvular" is open to criticism, unless it be clearly understood that the term has no reference to the mechanism of production.

A factor which may sometimes contribute to the production of the first sound as heard over the precordium is the sudden pressure of the contracting apex against the chest wall. The importance of this factor is also difficult to evaluate, but it is of interest that in cases with a sharp apex impulse the loudness of the first sound may sometimes be diminished by firm pressure with a finger over the area of the impulse.

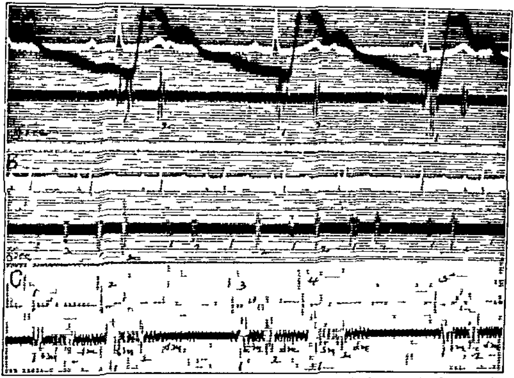

FIGURE 1. *A* Complete heart block. As the P-R intervals decrease the first sound becomes louder. The pulse remains about the same irrespective of the loudness of the first sound. *B* Ventricular escape and minor grade heart block with variations in loudness of the first heart sound depending on the As-Vs intervals. The first sound is loud when the P-R interval is comparatively short. *C* Variations of the first sounds in auricular fibrillation. In the second and fourth beats which are relatively premature the vibrations of the first sound are much larger than in the third and fifth beats. The second sounds in these four beats show little variation. High pitched systolic and low pitched diastolic murmurs are present.

In discussing the mechanism of production of the first heart sound Wiggers[3] has stated that sound intensity varies directly as the systolic tension developed within the ventricles and there is good reason to believe, with the tension developed during the isometric period of systole (the time between the beginning of ventricular systole and opening of the semilunar valves). A comparison of the time relationships of the first heart sound and the dynamic events of the heartbeat demonstrates

clearly that the major portion of the first heart sound occurs before the semilunar valves have opened. The sound would, therefore, appear to be synchronous with at least part of the period of rising tension within the ventricles. A study of the clinical material, however, does not support the view that the intensity of the sound varies according to the actual

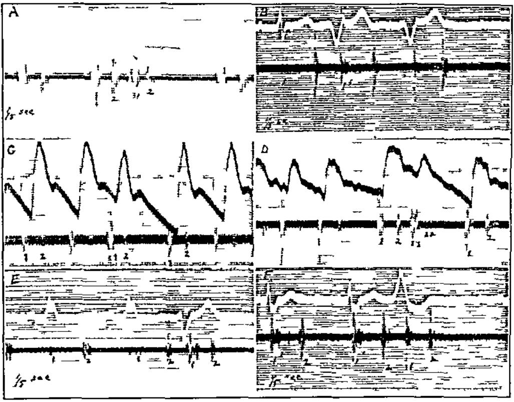

FIGURE 2. *The heart sounds in extrasystolic beats.* A. The first sound is represented by about the same pattern of vibrations in the extrasystoles as in normal beats. The *second sound in the extrasystole shows small vibrations and the interval between the first* and second sounds is decreased. B. The first sounds are louder in the extrasystoles than in the beat with the prolonged P R interval and normal type of ventricular complex. In the first extrasystole the first sound is split. C. The extrasystolic first sound is much louder than the first sounds in the beats with prolonged P R interval. D. Both the first *and second sounds of the extrasystole are split.* E. The first sound of the extrasystole shows much larger vibrations than the first sounds of the supraventricular beats in which left bundle branch block is present. F. The first sound is split in the supraventricular beats (showing right bundle branch block) whereas in the extrasystole it is single.

amount of elevation of intraventricular pressure during this period. Evidence bearing on this point may be summarized as follows.

1. It has been shown that the marked variations of intensity of the first heart sound usually present in complete heart block depend on the time relations of auricular and ventricular contractions.[7] These changes

in sound intensity are independent of changes in pulse volume (Fig 1) Similar changes in the first sound are also observed in other disturbances of cardiac mechanism in which varying auriculoventricular relationships occur, such as ventricular escape, extrasystoles (both auricular and ventricular), and paroxysmal tachycardia [8] It is easily demonstrable in the case of extrasystoles that beats with small pulses may have a first sound either decidedly louder or fainter than the adjacent normal beats, depending in part but not entirely upon the auriculoventricular relationship (Fig 2)

2 In mitral stenosis there is frequently a very sharp loud first sound irrespective of the blood pressure or the vigor of the heartbeat Conversely, in mitral regurgitation, the loudness of the first sound tends to be diminished and, in many cases, the sound cannot be heard even at the apex, though cardiac contraction may be carried out in a vigorous manner and the pulse volume be good

Observations of this type suggest that some other factor must be concerned in determining the intensity of the first heart sound Possibly the rapidity of rise of intraventricular tension may be more important than the height of tension developed The point may be illustrated in the following way If a string is suddenly snapped taut, a sound may be produced even though the tension is low, but if the application of tension is more gradual the sound will be less with the same or even greater tension The hypothesis as applied to the first heart sound however would be difficult to establish, since no method is available by which the rapidity of intraventricular pressure rise can be determined except in experimental animals There are some facts however, which would seem to favor the hypothesis

(1) In the case of mitral regurgitation, there may be retardation of the development of intraventricular tension due to leakage of blood (and therefore leakage of pressure) back to the left auricle during the early part of systole Wiggers and Feil[9] have shown that the amount of this regurgitation must be small Nevertheless, their curves of intraventricular pressure appear to show that the gradient of rise during the isometric period is less steep when regurgitation is present In mitral stenosis, on the other hand, rigidity of the valve leaflets which holds them near a position of closure may favor the rapid development of intraventricular tension (2) The marked differences in the first sound

associated with changes in auriculoventricular relationships may be due to the effect of auricular contraction on the position of the A-V valves. It has been demonstrated by Dean[10] that auricular systole causes marked changes in the position of the A-V valve leaflets. Considering this fact it logically follows that if the leaflets were near a position of closure at the beginning of ventricular contraction, intraventricular tension might be expected to rise more rapidly than if the leaflets were more widely opened so that some regurgitation of blood (and therefore pressure) back into the auricles occurred before valve closure.

There is a widely held clinical view that a loud first sound signifies a strongly acting heart, and a weak sound, a feebly acting heart. Wiggers[4] has supported this view, stating that the relative intensity of the sounds may be safely used as a clinical index of the vigor with which the ventricular contraction is carried out. There is some clinical evidence in favor of it: (1) In hearts with small ventricles showing quick wide excursions under fluoroscopic examination, the first sound tends to be loud and sharp. On the other hand, when the ventricles are enlarged and their excursions insignificant, the sound is frequently faint. (2) During conditions of marked depression of the circulation, such as are produced by surgical shock or severe infection, the first sound may be faint but with the onset of recovery and restored cardiovascular function, it becomes much louder.

On the other hand, the effects of A-V time relationships and disease of the mitral valve on the first sound do not support the view that the relative intensity of the first sound may be safely used as a clinical index of the vigor with which ventricular contraction is carried out, unless these factors are excluded. The auriculoventricular relationships and the function of the A-V valves in many cases are far more important in determining the loudness of the first sound than the actual vigor of contraction. Even in auricular fibrillation, in which the variable of auriculoventricular relationships does not have to be considered, the loudness of the first sound does not always vary in the same direction as the actual strength or force of the beat.[8] Thus, in some cases there may be no significant change in the relative intensity of loudness of the first sounds, even though great differences in successive pulse waves are present. This is most likely to occur in mitral stenosis. In other cases, premature beats

with small pulse waves may have first sounds either louder or fainter than the less premature beats.

In the paragraphs above, the thought in mind has been chiefly the significance of variations of the first heart sound as they apply to single cases. When an attempt is made to evaluate the first heart sounds in different cases, there are not only the factors mentioned above to deal with, but certain others in addition. Thus, lack of synchronism in its components may markedly modify the intensity of the sound. So-called reduplication or splitting is very common both in healthy and diseased hearts Registration of such sounds frequently shows clear-cut separation of two elements.[6] The cardiodynamic studies of Katz[11] show that perfect synchronism of contraction of the two sides is the exception rather than the rule, and studies of sound records would appear to bear out this view. When slight asynchronism is present but not enough to produce actual separation of two components, there may be merely prolongation of the sound and lessening of its intensity. This may cause the so-called muffled first sound. It is present in many cases in which there is no reason to regard the vigor of cardiac contraction as diminished

Among other factors to be considered are differences in shape of the chest wall, variations in the position of the heart, the varied composition and thickness of overlying tissues and their damping effect on the sound vibrations transmitted through them, and, finally, the extent of abdominal distention, especially the amount of gas in the stomach and its effects on the position and action of the heart and the resonance of the sounds.

Study of the first heart sound in over 500 cardiovascular cases[12] with special reference to the loudness of the sound yielded the following results: In general, youth, small heart size, thin chest wall, thyrotoxicosis, mitral stenosis and hypertension tended to be associated with a loud first sound Old age, thick chest wall, bradycardia, emphysema, shock, pericardial effusion, mitral regurgitation and myocardial disease, especially myocardial infarction, tended to be associated with a faint first sound. The above correlations were slight, however, as compared to the correlation between loudness of the first sound and duration of the P-R interval. Thus when the P-R interval was in the short normal range (0.12 to 0.14 second) the first sound tended to be loud; when the P-R interval was in the long normal range (0.18 to 0.20 second) the first sound tended to be faint, when the P-R interval was in the intermediate

range (0.15 to 0.17 second) the first sound tended to be of medium loudness. In persons with healthy hearts this correlation is remarkably good. It is exceptional to find, in the absence of heart disease, a loud first sound and a long normal P-R interval or a faint first sound and a short normal P-R interval.

In view of the considerations stated above, the clinician must be cautious in attempting to draw conclusions from the character of the first heart sound regarding the condition of the heart. He must take into account the various factors which are known to influence the loudness of the first sound.

In the above discussion no emphasis has been placed on the quality or timbre of the first heart sound, although clinicians can scarcely fail to be impressed by the probability that they are significant. A comparison of sound records made in different cases shows decided variations in the principal as well as the minor vibrations of first heart sounds. The imperfections of present methods of registration do not justify attempts to study the finer characteristics of the sounds. Although there are many exceptions to the rule, the tendency is to associate a so called "booming," or "muscular," low pitched and prolonged first sound with hypertrophied ventricular muscle, such as may occur in arterial hypertension, aortic insufficiency, or in the hearts of athletes. A short, sharp, higher pitched first sound is suggestive of mitral stenosis, hyperthyroidism or the effort syndrome. To what extent alterations in the character of the sounds, such as those mentioned, may be due to differences in muscle mass, thickness of fibers, extent or rapidity of their contraction, and the accompanying intraventricular pressure changes remains unknown.

Splitting of the First Heart Sound: It is obvious both from careful auscultation and analysis of sound records that the first heart sound is a complex phenomenon. It has long been recognized that at least two major components are often concerned in its production. At times these two components are sufficiently widely separated so that two distinct sounds may be recognized. This phenomenon has been called splitting or reduplication of the first heart sound. Comparatively little work has been reported, concerning the cause or nature of this splitting. The two chief views have been as follows. (1) The two components are of different origin. One is "muscular" and due to movement of interlacing cardiac fibers as they contract. The other is "valvular" and

due to forcible closure of the auriculoventricular valves in the early stages of contraction This hypothesis, which is the one most widely held, has led to the description of the first heart sound as predominantly "muscular" or "valvular" in quality. (2) The second view holds that the mechanism of production of the two components is similar in nature, one component being produced as a result of left ventricular contraction and the other as a result of right ventricular contraction. A necessary corollary to this view is that when the sound is split there must be asynchronism in the action of the two ventricles in at least some part of the early stage of contraction Although this hypothesis received some support in the earlier literature, it was discarded for a long time because the idea that the ventricles could exhibit asynchronism in contraction was regarded as untenable.[13] However, during the past few years, evidence has been produced to indicate that even healthy hearts may exhibit at least slight asynchronism in contraction of the two ventricles. Furthermore, evidence is available to suggest that one major component of the first sound may arise in the left ventricle and one in the right ventricle [6]

A certain amount of confusion has arisen in the literature because of the lack of a satisfactory definition as to just what constitutes the first heart sound Registration of the heart sounds reveals the fact that occasionally there may be as many as three separate groups of major vibrations in the time zone during which the first sound is supposed to occur. Likewise, groups of minor vibrations are frequently observed. At the present time any definition as to what constitutes the first sound must be regarded as arbitrary although definition is necessary if the subject is to be discussed without confusion.

Sound tracings frequently show minor vibrations resulting from auricular contractions which are not detected on auscultation. These vibrations may be regarded as the prototype of presystolic or auricular gallop sounds which will be discussed later. As a rule they begin in the range of 0 08 to 0 14 second after the beginning of the P wave. Thus, if the P-R interval is in the low normal range the sound vibrations may coincide with the beginning of the Q-R-S complex and at times the beginning of the Q R S complex may actually precede the beginning of these vibrations. If the disturbance is great enough to produce audible sound, the occurrence of this sound preceding the sound caused by

ventricular contraction may give the impression of splitting of the first sound In our opinion there are good practical reasons for not including this sound of auricular origin as a part of the first heart sound As a rule it begins even before the first electrical manifestation of ventricular activity and under these circumstances can be recognized clinically as presystolic Furthermore, this sound is nearly always a manifestation of gallop rhythm and should be recognized as such because of the important clinical significance of gallop rhythm The significance is apt to be missed if this grouping of sounds is called splitting or reduplication of the first sound

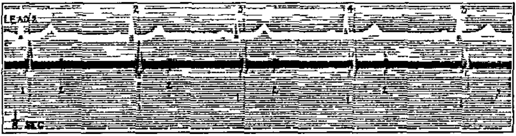

FIGURE 3 Phasic respiratory splitting of the first heart sound Beat two shows some merging of the two components beat three shows them side by side producing a so called muffled or prolonged first sound and beat five shows a separation of the two components

A short high pitched clicking or knocking early systolic sound (to be discussed later) is occasionally heard over the precordial area and is usually loudest in the second third or fourth interspace just to the right or left of the sternum The occurrence of this sound following the first heart *sound is apt to furnish an auditory impression of reduplication* However its area of maximum intensity its clicking or knocking quality and its occurrence at the instant of ejection of blood from the heart mark it off from what is ordinarily regarded as the first heart sound

In the normal healthy individual the first heart sound may be heard as a *single* or *double sound* *Variations associated with the phases* of respiration are not uncommon particularly in young people (Fig 3) Thus in a succession of beats extending through a complete respiratory cycle one may find single short sounds prolonged so-called muffled or impure sounds and splitting into two distinct components

A study of the time relations of single first heart sounds shows that the major vibrations usually begin in the range of 0 03 to 0 08 second after the beginning of the Q R S complex of the electrocardiogram and

before ejection of blood. Thus, the sound occurs during the isometric period of ventricular contraction.

For the purposes of this discussion, therefore, we define the first heart sound as a sound or grouping of sounds heard in the precordial area, associated with the act of ventricular contraction and occurring during the isometric phase of contraction of the ventricle from which each component of the sound arises. The reason for such a definition is to exclude sounds due to auricular contraction and those associated with the beginning of ejection from the ventricles, either of which, occurring in close association with the first sound, may be mistaken for true reduplication.

The phenomenon of reduplication, although of no great clinical significance, is of considerable importance to the investigator of the mechanism of production of the first sound. Until we are able to explain the nature of reduplication, we cannot expect to advance far in our understanding of the first sound. There is good evidence to support the view that most single first sounds include the two major components which, when they are sufficiently separated in time, are responsible for reduplication. It has been observed from time to time for years that in bundle branch block, there is apt to be reduplication of the heart sounds.[14] This finding suggested the possibility that reduplication of sounds in such cases might be related to asynchronism in contraction of the two ventricles. As stated above, Katz[11] had shown that in dogs, slight asynchronism in ejection from the two ventricles was a common occurrence. It therefore seemed possible that such might also be the case in humans and that this asynchronism might be considerable when bundle branch block is present.

An attempt to test this hypothesis by roentgenkymograms of aortic and pulmonic pulses timed by electrocardiograms showed that in left bundle branch block ejection into the aorta began several hundredths of a second after ejection into the pulmonary artery.[6] This delay in aortic ejection could be confirmed by simultaneous electrocardiogram and carotid artery tracing. In such cases both components of the sound preceded the carotid pulse. However, in certain ventricular extrasystoles interrupting left bundle branch block, carotid pulsation was found to occur earlier than during regular rhythm despite the smaller pulse and

consequently slower transmission to the carotid (Fig 3) In right bundle branch block however, no delay in aortic or carotid pulse has been found (unpublished observations) * Pulmonic artery pulsation in contrast to what was found in left bundle branch block, tended to lag behind aortic pulsation in cases with split first sounds One component of sound tended to precede and one to follow the beginning of the carotid pulse In cases with split first sounds and no bundle branch

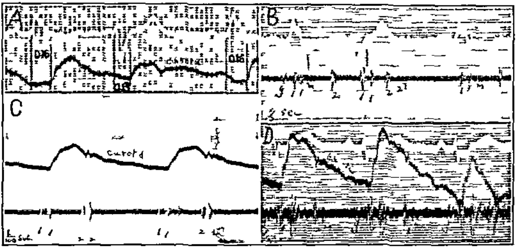

FIGURE 4 The relationship of split sounds to left ventricular ejection *A* Electrocardiogram and carotid pulse *B* Electrocardiogram and sounds Both *A* and *B* were made in a patient with left bundle branch block and ventricular extrasystoles Despite the prematurity of the extrasystole (which tends to cause delay in ejection) and the smallness of its pulse (which slows its velocity) the premature pulse falls relatively earlier than those of the supraventricular beats In the beats showing left bundle branch block both components of the split first sound precede the carotid upstroke In the extrasystoles the first component precedes and the second follows the carotid upstroke The vertical lines in *B* indicate the times of the carotid upstroke *C* Split first and split second sounds in left bundle branch block Both components of the split first sound precede the beginning of the carotid pulse The second component of the split second sound begins just ahead of the carotid incisura and represents aortic closure *D* The relations between ejection and split first sounds in right bundle branch block The first component of the first sound preceded the carotid upstroke and the second followed considerably later The first component of the split second sound begins just before the carotid incisura and represents aortic closure The tracings in this figure reflect part of the evidence indicating that in left bundle branch block left ventricular ejection is delayed and that in right bundle branch block left ventricular ejection does not tend to be delayed

block, there was also found asynchronism in the beginning of ejection into the two great vessels

These data seemed to favor the view that splitting of the first sound at least in certain cases was associated with asynchronism in the begin

* There is one exception to this statement In premature beats with a feeble pulse the beginning of ejection may be greatly delayed without corresponding delay in the first heart sound (Unpublished observations.)

ning of ejection from the two ventricles and that, in all probability, one component was produced in each ventricle However, the evidence which we regarded as most important in favor of this view was of a different type We have mentioned above the fact that the time relation of auricular and ventricular contraction may have a very important effect on the loudness of the first sound This is reflected *in sound tracings by* variation in amplitude of recorded vibrations

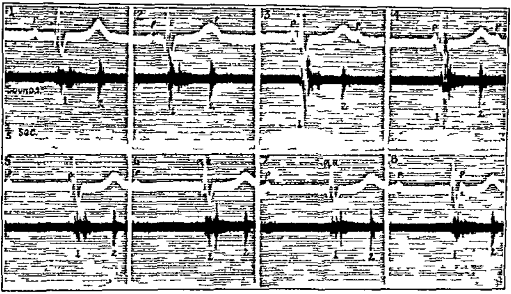

FIGURE 5 Complete heart block and split first heart sounds Beats were selected from a continuous strip of tracing to show the effect of varying As-Vs relations on each component of the split first sound Either component may be represented by small or large vibrations depending on its own time relation to auricular contraction

It seemed therefore that if cases could be found which showed constant splitting of the first heart sound and varying auriculoventricular relationships from beat to beat, it would be interesting to observe the behavior of each component of the first sound We have had the opportunity to study two such cases in considerable detail [15] In both cases each component of the first sound was influenced by its own time relationship to auricular contraction (Fig 5) Thus, in any given beat both components might be represented in the tracing by (1) large vibrations (2) small vibrations (3) the first component having large vibrations and the second small vibrations, or (4) the first component having small vibrations and the second large vibrations It seemed to us that such behavior could not be accounted for if both components arose in

a single ventricle, but on the other hand made necessary the hypothesis that one of the two major components arose in each ventricle

Although the evidence mentioned above would appear to indicate that in split first sounds each ventricle contributes a component the possibility cannot be denied at present that in certain cases splitting of the sound in one ventricle may occur However there is as yet no valid *evidence to support such a view*

When the two major components of the first sound are clearly separated it is noted that each is of extremely short duration usually less than that ordinarily found in the first sound (Fig 3) It is probable therefore that in single first sounds both components are usually present and partially superimposed If the asynchronism is a little greater so that the two components are recorded side by side but not actually separated the muffled or impure first sound results However in some cases there appears to be only a single component to the first sound The clearest example is seen in certain cases of left bundle branch block which exhibit a first sound a pause and then a systolic murmur an auscultatory finding pointed out by King[14] In such cases the sound in all probability *emanates from the right ventricle In cases without bundle branch block* but with very short single first sounds—the type often described as valvular—one may venture to think that this quality is due to the fact that only one component is loud enough to be heard

When we consider how the first sound is actually produced it is clear that the dynamic factor must be ventricular contraction Available evidence points to the view that the major vibrations occur during the isometric period of ventricular contraction and probably while intraventricular *pressure is rising rapidly This force sets up vibrations which* are quickly damped What structure or structures are actually set into vibration in such fashion as to produce sound has not as yet been established Some workers adhere to the view that the auriculoventricular valves are the important source of vibrations[16] whereas some believe that various other structures are also concerned[17] So far as we are aware the evidence available at present does not clearly establish either view Furthermore we do not know just what it is that governs the magnitude of the vibrations and therefore the loudness of the sound It seems probable that the significant factor is the gradient of the rise of intraventricular pressure (the amount of force in terms of the speed

of its development) in each ventricle and its effect on setting ventricular structures into vibration. Such an hypothesis, whether eventually proven to be valid or not, appears to account better than any other now available for the behavior of the first sound.

THE SECOND HEART SOUND

It may be regarded as established that the second heart sound is produced by after vibrations due to closure of the semilunar valves. This sound has two components, one furnished by aortic closure and the other by pulmonic closure. According to Wiggers,[3] the shortness of the sound is due to the quickness with which the vibrations are damped by the friction of the blood and lessening of their frequency as the pressure falls

Wiggers[17] states that the intensity of the aortic and pulmonic second sounds varies roughly with the mean pressures in the respective circuits, but that dynamic studies show them to be more definitely related to the actual pressures existing in the large vessels at the very beginning of diastole. It is questionable whether or not Wiggers' view is adequate. It fails to explain the fact that extrasystoles and the more premature beats during auricular fibrillation sometimes have second sounds as loud as more effective beats (Figs. 1 *C* and 2 *B*). Furthermore, the fact that the pulmonic second sound may be quite as loud as the aortic, even though the pressure at the moment of closure must be very much lower, suggests that factors other than the actual level of pressure play an important part.

It would seem possible, therefore, that the difference in pressure in a ventricle and in its corresponding great vessel, which must govern the speed of closure of a semilunar valve, might be as important as the actual level of pressure in responsibility for the intensity of the sound Thus, if the gradient of fall of intraventricular pressure were comparatively steep just prior to valve closure, movement of the valve toward the position of closure should be correspondingly rapid and the after vibrations correspondingly more intense and productive of a louder sound.

Clinicians have long taken into account another factor which must be concerned in the production of the second sound, *viz.*, the physical state of the valve leaflets The character of the sound should depend not only on the speed and the pressure of closure, but also on the capacity of the valves to be set into vibration, analogous to the string or reed of

a musical instrument. This factor has received much attention in connection with the aortic second sound.

To how great an extent thickening or disease of the aortic leaflets modifies the aortic second sound is not known with certainty. The accentuation attributed to this factor may be due partly in some cases to a more anterior position of the ascending portion of a normal aorta or to dilatation, or tortuosity, and, consequently, better transmission of the second sound to the surface Whatever may be the actual mechanism concerned in the change in sound, either an accentuation or a definitely higher pitch of the aortic second sound (in the absence of hypertension) should immediately lead to suspicion of thickening of the valve leaflets or disease of the aorta. On the other hand, marked diminution or absence of the aortic second sound, not accounted for by low blood pressure, should suggest lessened mobility of the valve and lead to a careful search for aortic stenosis or insufficiency.

Arterial hypertension tends to cause increased loudness and higher pitch of the aortic second sound. However, the enormous variability of the sounds in patients with similar degrees of hypertension is most impressive. Satisfactory explanations for these differences are not available but they may be due at least in part to factors discussed above.

The various diseases that are known to cause hypertension in the pulmonary arterial system, such as pulmonary arteriosclerosis, pulmonary emphysema, congenital defects with left to right shunt, and certain types of left sided heart disease (particularly mitral stenosis), frequently have associated with them accentuation of the pulmonic second sound The main change is usually in loudness of the sound rather than pitch and timbre, in this, it tends to differ from the aortic second sound Before deciding whether the pulmonic second sound is altered from the normal, however, the examiner should always take into account the age of the patient as well as the thickness of the chest wall In youth and in the thin-chested, the sound tends to be comparatively louder.

Splitting of the Second Heart Sound: Splitting or reduplication of the second sound is very common in both healthy and diseased hearts. Two so called types have been described: That due to asynchronous closure of the aortic and pulmonic valves: and that due to asynchronous closure of leaflets of either valve. Whether or not the latter type occurs is doubtful; in most cases the reduplication is clearly due to asynchronism

in closure of the two valves. It is present in many cases of bundle branch block[6] (Fig. 4 C) and of ventricular extrasystoles as well (Figs. 2 B, D and E) unless the beat is *highly premature and ineffective*. It may be discovered in many cases with reduplication of the first sound whether the heart is healthy or diseased. On the other hand it occurs frequently when no splitting of the first sound is discoverable.

There are at least two reasons why the second sound may be split when the first sound is not. In the first place the components of the second heart sound are shorter in duration than those of the first; therefore an equal grade of asynchronism might merely prolong the first

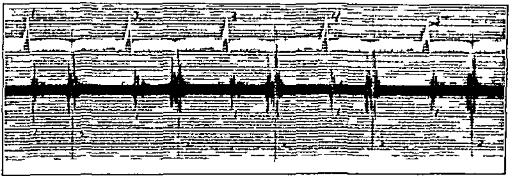

FIGURE 6. Phasic respiratory splitting of the second heart sound. In the first and fifth beats the two components are approximated closely enough to give the impression of a prolonged second sound. In beat three they are completely separated.

sound without causing separation, whereas it might bring about clean cut separation in the second sound that could be both heard on auscultation and registered in sound tracings. Secondly, the length of dynamic systole in the two ventricles may vary.[11] This is probably best exemplified in certain cases which in different phases of respiration show no change in the duration or frequency of the vibrations of the first sound whereas the two components of the second sound may vary in position from superimposition to complete separation and reduplication (Fig. 6). The observations of Katz[11] indicate that these changes may be dependent on variations of blood inflow to the two sides of the heart during the different phases of respiration or to vagus effect.

THE MID SYSTOLIC CLICK

In 1913 Gallavardin[18] described a clicklike sound which occurs during ventricular systole and falls between the first and second heart sounds. In discussing this finding he applied two terms to it, namely

'pseudo reduplication of the second heart sound" and "telesystolic extra cardiac sound" We have suggested the less cumbersome term of mid-systolic click [19] The chief objection to this term is that the sound does not necessarily fall in mid systole, but may occur earlier or later than this point Lian and Deparis[20] independently called the sound Le Claquement meso systolique pleuro pericardiale,' a term very similar to ours except for the last word which refers to Gallavardin s and their own

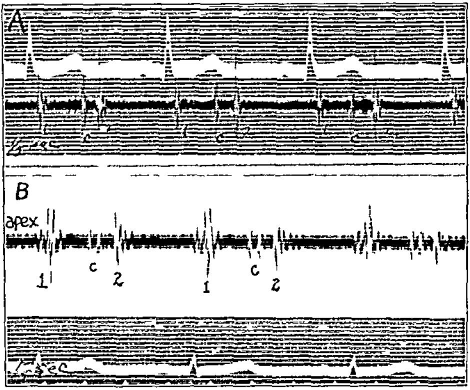

Figure 7 The mid systolic click A Variation in time relations to first and second heart sounds B A double click

conception of the mechanism of production of the sound Gallavardin stated that in three cases which had exhibited the sound during life pleuro pericardial adhesions were found at necropsy He believed, therefore, that the sound is produced by tugging on pleuro pericardial adhesions during systole, a view which at this time cannot be regarded as established The clicklike sound can be imitated in the cadaver by moving the heart against a subpleural emphysematous bulla with the lung applied to the inner chest wall while one auscults over this area Furthermore the sound is similar to that which can be produced by

injecting air into the mediastinal tissues (unpublished observations)

The sound is a click or crepitating noise not at all like any sound known to be produced within the heart except the opening snap of mitral stenosis which it sometimes resembles in quality but not in time relations It is usually a single sound but there may be two or even three sounds in rapid succession which may give the auditory impression of a short friction (Fig 7) It is usually heard best near the apex but occasionally as high as the third interspace It is often loud enough to be heard over the entire precordium Although it tends to fall about midway between the first and second sounds it may be near enough to one or the other to be mistaken for reduplication by those who disregard its other qualities In many cases there is a phasic respiratory variation in its time relations to the first and second sounds so that in one phase of respiration it may be nearer to the first sound and in another nearer to the second sound

The mid systolic click is quite common although usually overlooked by those who are not familiar with its characteristics So far as we have been able to ascertain it has no pathological significance It is usually found in healthy individuals but occasionally is present in patients with one or another type of heart disease Its chief clinical importance is that it is sometimes wrongly interpreted and mistaken for evidence of heart disease It is for this reason that all who examine hearts should be able to recognize it

GALLOP RHYTHM AND THE THIRD HEART SOUND

The presystolic type of gallop or canter rhythm was clearly described as early as 1838 by Charcelay[21] Potain[22] however has been the most important contributor to this subject He divided gallop rhythm into three types protodiastolic mesodiastolic and presystolic and distinguished them from splitting of the first and second heart sounds He also stated that the gallop sound could be heard in 20 per cent of normal individuals Potain s classification has been modified in two respects (1) Following the work of Gibson[23] and of Thayer[24] the protodiastolic sound heard in individuals with healthy hearts most frequently in children and young adults has been called the physiological third heart sound There has been a tendency to remove this sound from the category of gallop rhythm despite the fact that Thayer believed that protodiastolic gallop and third heart sounds were produced by analogous

if not identical mechanisms. (2) Most recent writers have denied the existence of a separate mesodiastolic type of gallop, stating that either a protodiastolic or presystolic sound will occupy a mid-diastolic position if the heart rate is rapid enough and that mid-diastolic gallop sounds do not occur under any other circumstances. According to this conception,

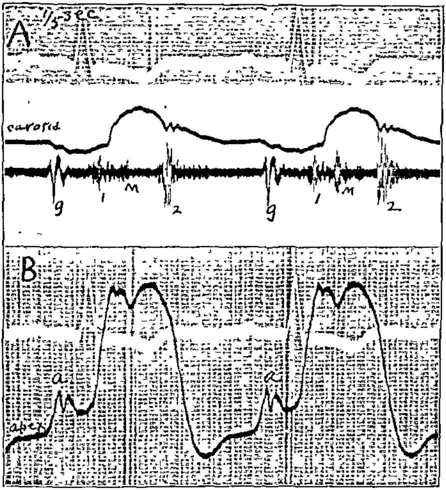

FIGURE 8. Presystolic gallop rhythm. *A*, Electrocardiogram, carotid pulse and sounds at the apex. The gallop sound is represented by vibrations of much lower frequency than the first sound, the systolic murmur or the second sound. *B*, Electrocardiogram and apex cardiogram. The summit of the prominent presystolic wave (*a*) occurs at the same time as the gallop sound.

so-called mesodiastolic gallop rhythm is in reality due either to protodiastolic or presystolic gallop.

Many discussions of gallop rhythm have been somewhat confusing because of failure to differentiate clearly gallop sounds from other sounds which superficially resemble them. The differentiation among

the various types of sounds is for the most part not difficult, except that the physiological third heart sound cannot be distinguished from protodiastolic gallop rhythm on the basis of the sounds The sounds to be considered are: (1) The so-called systolic gallop or other sounds which

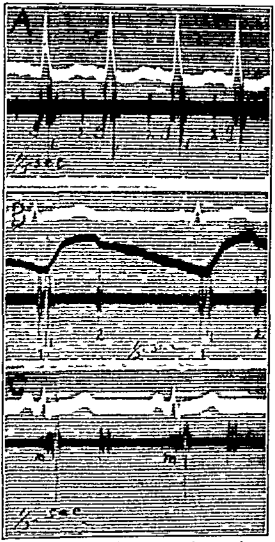

FIGURE 9 *A* Presystolic gallop rhythm (*g*) simulating splitting of the first heart sound *B* Splitting of the first heart sound *C* Presystolic murmur (*m*) The close grouping of the gallop and first sounds as in *A* make its auscultatory differentiation from split first sounds such as are seen in *B* difficult. Both are often mistaken for a presystolic murmur and first sound such as is shown in *C*

occur during systole, (2) reduplication of either the first or second sound, (3) the opening snap of mitral stenosis, and (4) the sound due to calcification of the pericardium The characteristics which differentiate them are noted in the appended table

The presystolic gallop sound is clearly a result of auricular contraction, as was first stated by Charcelay No dependable report of presystolic gallop in the absence of auricular beats is to be found in the literature We have never recorded it when it was not in close association with the P wave of the electrocardiogram In nearly all cases it is initiated within a range of 0 08 to 0 14 second after the beginning of the P wave If the

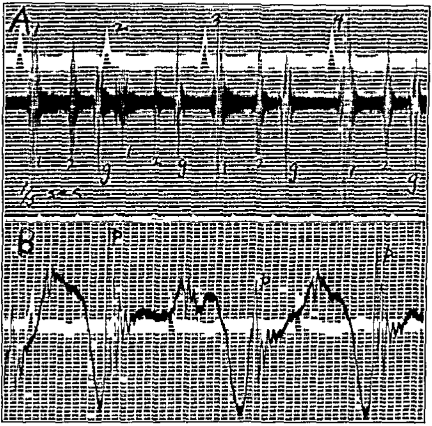

FIGURE 10 Protodiastolic gallop rhythm *A* Loud gallop sounds in auricular fibrillation The interval between the second and gallop sound (g) is less in beat two than in beat four This variation is dependent on the duration of the preceding ventricular diastole *B* *Apex cardiogram same patient The large protodiastolic wave (p) falls at* the time the gallop sound is to be expected The time relations of the protodiastolic wave show the same variations as those of the gallop sound

sounds are recorded in conjunction with an apex cardiogram it is found that the gallop sound falls at the peak of the wave produced at the apex by auricular contraction (Fig 8) For these reasons we believe that the name might properly be changed from presystolic to auricular gallop as has been suggested[25] The time relations of the sound are determined solely by the position of auricular systole It is usually "presystolic

because auricular systole usually falls shortly before ventricular systole. When auricular systole moves to some other position in the cardiac cycle, auriculosystolic gallop moves along with it. If the A-V interval is very short, the gallop sound may be so close to the first sound as to simulate splitting of the first sound (Fig. 9 *A*).

Protodiastolic gallop occurs within the range of approximately 0.12 to 0.20 second after the beginning of the second sound. In quality and the areas of maximum intensity, the protodiastolic sounds are indistinguishable from presystolic gallop sounds. This sound falls at the summit of the wave of early diastolic ventricular filling. The statement has been made repeatedly in the literature that gallop rhythm does not occur in the presence of auricular fibrillation. This statement is true only so far as presystolic gallop sounds are concerned. Protodiastolic gallop rhythm occurs not infrequently in the presence of auricular fibrillation (Figs. 10 and 12 *B*).

Summation Gallop Rhythm: It has long been known that gallop rhythm is most apt to be present when the heart rate is rapid, at least 100 beats per minute. Furthermore, it has been noted that prolonged auriculoventricular conduction time in some way favors the occurrence of gallop rhythm. Gubergritz[26] suggested that presystolic and protodiastolic sounds were due to similar mechanisms and in support of this view cited the observation that at various times the same patient might show one or the other type of gallop sound. We have been able to confirm this observation by recording heart sounds, and we have also found that both types may be present at the same time (Fig. 11 *A*). Furthermore, it has been possible to show that various forms of cardiac mechanism which tend to superimpose auricular contraction on the wave of early diastolic ventricular filling favor the production of gallop rhythm.[27] If either presystolic or protodiastolic gallop rhythm had previously been present, the coincidence of auricular contraction with early diastolic filling greatly increases the loudness of the sound (Figs. 11 and 12). If both protodiastolic and presystolic gallop sounds are present, increase in heart rate *decreases the interval between them.* If the rate goes above 100 they are apt to merge, with the production of a single sound much louder than would be expected from simple addition of the two sounds. In 1933 we presented evidence showing the relationship between the behavior of gallop rhythm and the

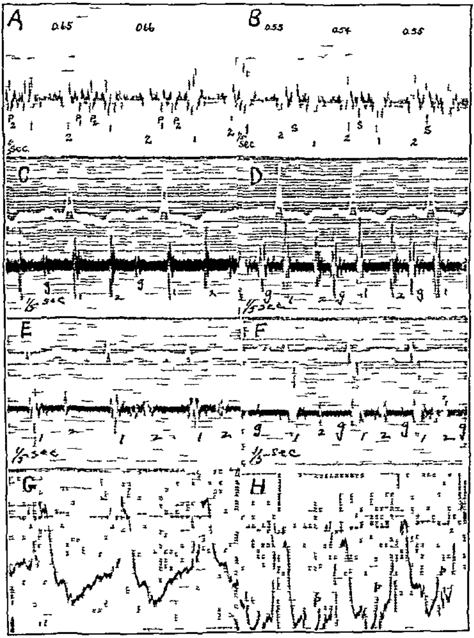

FIGURE 11 The effect of heart rate on gallop rhythm *A* and *B* from same patient In *A* both protodiastolic (*p* 1) and presystolic (*p*-2) gallop sounds are present In *B* the heart rate is accelerated so that the gallop sounds are merged into summation (*s*) gallop *C* and *D* from one patient The protodiastolic gallop sound (*g*) becomes much louder when the heart rate is increased *E F G* and *H* from one patient. When the rate is increased (*F*) gallop rhythm (*g*) makes its appearance and a diastolic wave (*p*) in the apex cardiogram (*H*) becomes prominent

time relations of early diastolic and auriculosystolic ventricular filling.[27] The term "summation gallop" was used to refer to the gallop sounds either produced or intensified by coincidence of the two waves of ven-

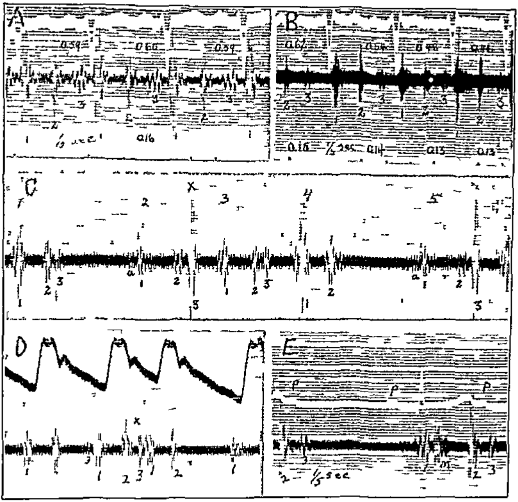

FIGURE 12 Effects of occurrence of auricular contraction in early ventricular diastole on the production of gallop sounds *A* and *B* Same patient In *A* incomplete summation gallop rhythm is present producing a prolonged gallop sound (3) In *B* the rhythm has changed to auricular fibrillation so that only faint much shorter protodiastolic gallop sounds (3) persist *C* Incomplete heart block The gallop sound (3) is present only when the P wave occurs near the end of the T wave The most favorable position is just at the end of the T wave (beats two and five) *D* In the premature beat the P wave coming just at the end of the preceding ventricular systole causes a summation gallop sound (3) *E* Two to one heart block The auricular beat falling before the ventricular beat causes only minor sound vibrations The auricular beat falling in early diastole causes a distinct gallop sound (3)

tricular filling Further studies during the past six years have confirmed the validity and usefulness of the concept of summation gallop This concept permits at least some understanding of what was formerly

regarded as mysterious behavior. Most physicians, unless they are constantly on the lookout for faint dull low-pitched gallop sounds, rarely detect any type except summation gallop. Nearly all the loud gallop sounds which obtrude themselves on the ear are of this type. The criticisms which have been offered against the hypothesis of summation[25] had all been covered by the evidence presented in the original paper and have therefore required no further consideration

Clinical Characteristics: Potain has said that gallop sounds can some times be palpated better than heard He was doubtless referring to the impact of the wave of ventricular filling which accompanies the gallop sound. To recognize gallop rhythm one must be familiar with *the low pitch of the sound, the positions in the heart cycle it is apt* to occupy, the positions at which it is best heard (the apex or fourth interspace just to the left of the sternum) and the maneuvers which tend to accentuate it (such as placing the patient in the left lateral recumbent position, or employing some method to increase the heart rate).

Gallop sounds are very variable in their behavior They are usually, but not always, best heard with the patient in the recumbent position They may be present during one examination and absent at the next They may even appear or disappear during a single application of the stethoscope if the rate changes (see Fig. 11). They tend to be more conspicuous during decompensation and may disappear with the recovery of compensation.

Gallop rhythm is usually "left sided" and heard best at the apex, except in hypertensive disease with heart failure when it is frequently "right-sided" and heard best in the fourth interspace just to the left of the sternum. Apical gallop sounds are almost certainly produced in the left ventricle and those heard near the midline probably in the right ventricle

Mechanism: The actual mechanism of production of gallop sounds has not been clearly demonstrated. Some workers believe that the additional sound is produced by vibrations set up in the auriculoventricular valves.[10] *Others incline to the view that the wave of ventricular filling* transmits an impact through the ventricular wall to adjacent structures such as the chest wall, setting them into vibration.

Those who believe that gallop sounds are valvular in origin may be divided into two schools, namely, those who hold that the sounds are due to opening of the valves, and those who maintain that they are

the finger against lung tissue applied to the inner chest wall and auscultating over the outside of the chest. It is a remarkable fact that gallop rhythm is not often heard with the patient in the upright position. However, in those cases in which it is heard in the upright position, it is apt to be much louder in the recumbent position. The most favorable position for eliciting gallop rhythm is usually the left lateral decubitus It is not quite clear what bearing these facts have on the mechanism.

The conception of gallop rhythm presented above has a definite bearing on prognosis. Thus, the larger the wave of filling or the greater its velocity, the less is the change necessary in the state of the heart muscle for the production of gallop rhythm. In hyperthyroidism with more rapid circulation time, and, because of tachycardia, only a single large wave of ventricular filling, it is quite probable that gallop rhythm (summation type) may occur with little alteration from the normal state of the heart muscle. On the other hand, as stated above, when the heart muscle is severely diseased there is good reason to believe that gallop rhythm may occur in spite of little change from the normal in the wave of filling. The prognosis, therefore, may be modified by various factors. In such conditions as hyperthyroidism, anemia, or acute carditis, it is apt to be determined by the course of the underlying disease. Thus, while gallop rhythm may still be interpreted as the cry of a heart for help,[29] the distress is not necessarily irremediable Studies made in groups of cases showing gallop rhythm indicate that on the whole this disturbance has a serious prognostic significance. Such studies are of great value. Nevertheless, one must guard against the fallacy of venturing a prognosis in any patient on the basis of gallop rhythm alone, any more than on any other single finding. Gallop rhythm is a danger signal but one must still discover the nature and gravity of the danger.

be difficult to determine to what extent these vibrations may be adventitious due to movements of the auricles against the output receiver. Such a finding does not permit the assumption that a sound is being produced within the auricles. For example gently tapping the diaphragm of a stethoscope produces a sound which seems quite loud as one listens through the ear pieces; the cause of such a sound however is not movement of the finger *per se* but its impact against an interposed structure capable of being set into vibration.*

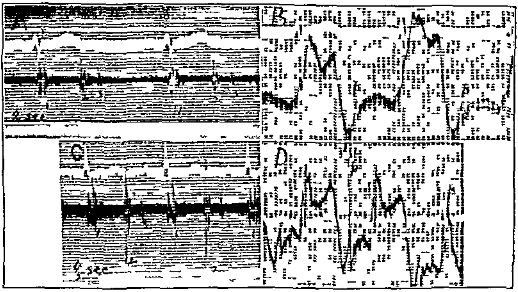

FIGURE 15. The physiological third heart sound. *A* and *B*, Same patient. *C* and *D*, Same patient. In each case there is a prominent protodiastolic wave (*p*) in the apex cardiogram at the instant the third heart sound (*S*) occurs.

The phenomenon of summation affects the physiological third heart sound as it does gallop rhythm. There are, however, important differences. In gallop rhythm there is usually good reason for believing that waves of ventricular filling are increased in velocity or size or that there is some disease of the heart muscle. In the healthy young people with

* This factor may have considerable importance even when sounds are heard or recorded from the surface of the chest provided impact is transmitted through the chest wall at that instant. There can be little doubt that impact against the inner chest wall contributes to various sounds heard through the stethoscope or recorded. These may be regarded for practical purposes as component parts of a heart sound although the actual place of origin of the vibrations is outside the heart. However, vibrations set up in an output receiver because of the transmission of an impact through the chest wall (vibrations which would not be present except for the interposed output receiver) should not be regarded as a legitimate part of heart sounds but should be looked upon as an imperfection in technic.

due to closure The view that gallop sounds are due to opening of the auriculoventricular valves in diastole is easily ruled out by consideration of the time relationships, since the sound falls at the summit of the protodiastolic wave of ventricular filling which comes several hundredths of a second after opening of the valves Those who believe the sounds are due to valve closure assume that waves of ventricular filling by reflection back of the valves, push them to a position of closure, thus causing a sound This hypothesis does not seem to us to be valid for the following reasons (1) The sound comes at the summit of the wave of

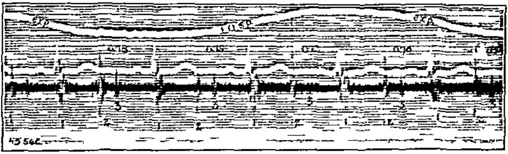

FIGURE 13 The effect of respiration on third sounds In this case the third sounds (3) were *loudest just at the end of expiration and faintest when the lungs were filled.*

filling as recorded in the apex cardiogram (Figs 10 and 11) and during the downstroke of the jugular V wave If it were due to valve closure it should come after the summit of the filling wave, furthermore in right sided gallop if valve closure occurred at the instant of the gallop sound there should be an interruption in the downward curve of the jugular tracing at the same instant since the emptying of the venous system would be checked if the A V valves were closed However such is not the case The downward curve may continue uninterruptedly for at least 0 02 or 0 03 second after the beginning of the gallop sound (2) All sounds that we know to be valvular in origin are much higher in pitch and tend to be shorter in duration than gallop sounds

A wave of ventricular filling is indispensable for the production of gallop rhythm *Anything tending to increase the size or velocity of* such a wave favors the production of a gallop sound Among such factors are fever anemia *hyperthyroidism or heart failure with increased* intraauricular pressure In some cases, a third sound can be heard during only a part of the respiratory cycle (Fig 13) *Occasionally*

alternation in the gallop sound is present (Fig 14) Both of these phenomena are probably due to variations in the waves of ventricular filling Other factors known to favor the production of gallop rhythm aside from the summation phenomenon discussed previously are such diverse conditions as acute rheumatic carditis the so called anterior or apical myocardial infarction and the dilated failing heart of hyper

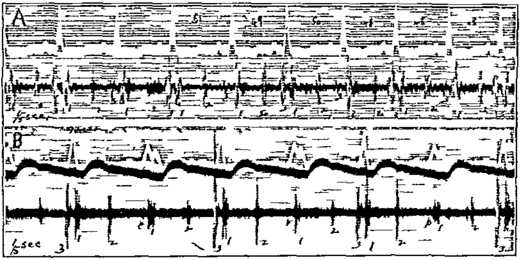

FIGURE 14 *Alternation in gallop sounds* *A* True alternation in which the gallop sounds (3) were alternately quite loud and faint Although ventricular alternation was present no definite alternation in loudness of either first or second sounds was detected *B* Pseudo alternation of gallop sounds (3) due to left bundle branch block in alternate beats *The onset of left ventricular diastole is delayed when left bundle branch block* present so that the following auricular contraction occurs early enough in ventricular diastole to produce summation and therefore a loud gallop sound (*d*)

tensive disease It seems probable that in such conditions the altered state of the heart muscle may offer less resistance to the impact of waves *of ventricular filling Available evidence suggests that in some cases the* increased waves of filling are chiefly responsible for the production of the gallop sound in others myocardial change However the combination of these two factors is most apt to produce gallop rhythm

The low pitch of the sounds their areas of maximum intensity their time relations to the waves of ventricular filling the prominence of these waves in apex cardiograms their palpability when gallop rhythm is present and the important bearing which the state of the ventricular muscle (but not the valves) has on the production of gallop sounds would all seem to favor the impact hypothesis The sound can be quite faithfully reproduced in the cadaver by gently tapping

the finger against lung tissue applied to the inner chest wall and auscultating over the outside of the chest. It is a remarkable fact that gallop rhythm is not often heard with the patient in the upright position. However, in those cases in which it is heard in the upright position, it is apt to be much louder in the recumbent position The most favorable position for eliciting gallop rhythm is usually the left lateral decubitus. It is not quite clear what bearing these facts have on the mechanism.

The conception of gallop rhythm presented above has a definite bearing on prognosis. Thus, the larger the wave of filling or the greater its velocity, the less is the change necessary in the state of the heart muscle for the production of gallop rhythm. In hyperthyroidism with more rapid circulation time, and, because of tachycardia, only a single large wave of ventricular filling, it is quite probable that gallop rhythm (summation type) may occur with little alteration from the normal state of the heart muscle. On the other hand, as stated above, when the heart muscle is severely diseased there is good reason to believe that gallop rhythm may occur in spite of little change from the normal in the wave of filling. The prognosis, therefore, may be modified by various factors. In such conditions as hyperthyroidism, anemia, or acute carditis, it is apt to be determined by the course of the underlying disease Thus, while gallop rhythm may still be interpreted as the cry of a heart for help,[29] the distress is not necessarily irremediable. Studies made in groups of cases showing gallop rhythm indicate that on the whole this disturbance has a serious prognostic significance. Such studies are of great value. Nevertheless, one must guard against the fallacy of venturing a prognosis in any patient on the basis of gallop rhythm alone, any more than on any other single finding. Gallop rhythm is a danger signal but one must still discover the nature and gravity of the danger.

The Physiological Third Heart Sound: This sound, which is very commonly present in healthy children and not infrequently in young adults, has auscultatory characteristics identical with gallop sounds. Over the chest wall, the sound heard is nearly always protodiastolic. Low frequency vibrations may sometimes be recorded during the presystolic period, but are only rarely audible.[30] However, as long ago as 1914, Benjamins[30a] and more recently Taquini[30b] have recorded vibrations corresponding in time to auricular contraction when output receivers were placed in the esophagus at the auricular level. It would

be difficult to determine to what extent these vibrations may be adventitious due to movements of the auricles against the output receiver Such a finding does not permit the assumption that a sound is being produced within the auricles For example gently tapping the diaphragm of a stethoscope produces a sound which seems quite loud as one listens through the ear pieces the cause of such a sound however is not movement of the finger *per se* but its impact against *an interposed structure capable of being set into vibration* *

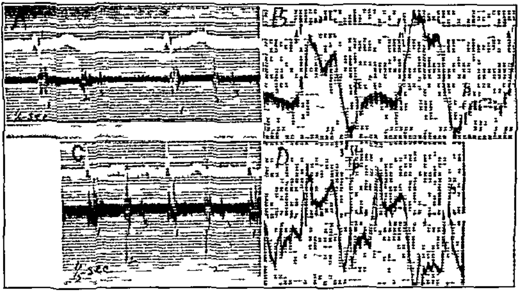

FIGURE 15 The physiological third heart sound *A* and *B* Same patient *C* and *D* Same patient In each case there is a prominent protodiastolic wave (*f*) in the apex cardiogram at the instant the third heart sound (3) occurs

The phenomenon of summation affects the physiological third heart sound as it does gallop rhythm There are however, important differences In gallop rhythm there is usually good reason for believing that waves of ventricular filling are increased in velocity or size or that there *is some disease of the heart muscle In the healthy young people with*

* This factor may have considerable importance even when sounds are heard or recorded *from the surface of the chest provided impact is transmitted through the chest wall at that* instant There can be little doubt that impact against the inner chest wall contributes to various sounds heard through the stethoscope or recorded These may be regarded for practical purposes as component parts of a heart sound although the actual place of origin of the vibrations is outside the heart However vibrations set up in an output receiver because of the transmission of an impact through the chest wall (vibrations which would not be present except for the interposed output receiver) should not be regarded as a legitimate part of heart sounds but should be looked upon as an imperfection in technic

physiological third heart sounds, there is no reason for believing any of these factors to be present. If, therefore, the sounds have a similar mechanism, it is necessary to postulate that in youth the heart muscle possesses some quality that later tends to be lost. Such a quality might be a certain pliability or elasticity, which would permit the impact of the wave of ventricular filling to be transmitted through the ventricular wall more readily than occurs in older, less elastic muscle. We have no proof to offer for such a view except for the fact that in apex cardiograms, rather large waves are found, corresponding in time to the third sounds, just as in the case of gallop rhythm (Fig. 15). If this view is correct, the mechanism of the physiological third heart sound is closely related to that of gallop rhythm The question may be asked why it is that, when the rate is slow enough to avoid summation, presystolic physiological third heart sounds are so much less frequently heard than presystolic gallop sounds This may be due to the fact that in the young healthy heart, with no tendency to increased venous pressure, the auricle is not likely to contain a large amount of blood in the latter part of ventricular diastole, when auricular systole occurs, so that a large wave of ventricular filling would not be expected at that time.

THE PROTODIASTOLIC SOUND ASSOCIATED WITH CALCIFICATION OF THE PERICARDIUM

In 1933, Lian, Marchal and Pautrat[31] described a "strong vibrating" sound heard in early diastole in two patients with calcification of the pericardium. They termed it protodiastolic pericardiac vibration. We have observed and recorded this sound in several patients. The time relations of the sound are identical with those of protodiastolic gallop rhythm although the sound tends to be much sharper, higher-pitched, and louder It has associated with it a vigorous apex impulse which falls at the same instant as the sound (Fig 16) The mechanism of the sound production is probably somewhat similar to that of gallop rhythm, with the sheet of calcium influencing the production of sound vibrations in some way as yet not understood. We have noted the loud sound only in cases with circumscribed calcified areas In one case in which the heart was found to be almost completely encased in calcium.

a faint sound with similar time relations could be heard only near the base. The area over which the sound is audible appears to depend on its loudness.

SYSTOLIC GALLOP RHYTHM

The term meso-systolic gallop was first proposed by Cuffer and Barbillon[32] who have received credit for the discovery of systolic gallop

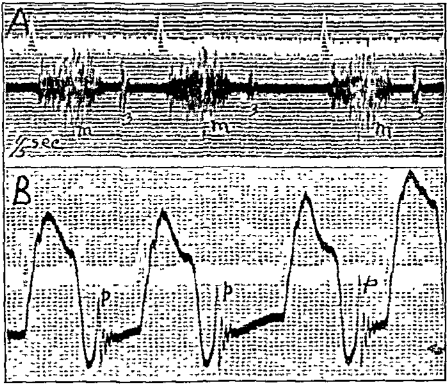

FIGURE 16 The protodiastolic pericardiac vibration. A and B, Same patient There was a loud systolic murmur (m), a sharp third sound (3) and at the same time a sharp outward thrust at the apex (p).

rhythm. However, the descriptions to be found in their article are vague and give the impression that they were mistaking such common conditions as splitting of sounds and diastolic types of gallop rhythm for systolic gallop. However, Potain[33] a little later clearly described the aortic type of systolic gallop rhythm. There has been, more recently, a tendency to include the mid-systolic click, with the systolic gallop sound.[34,35] The aortic systolic gallop sound falls about midway between the first and second sound. There is remarkable constancy in its time relations from beat to beat. It is a little higher in pitch than diastolic

gallop sounds but has none of the clicking or crepitating character of the mid systolic click. It is heard best in the aortic area. It may occur in cases with typhoid or typhoidlike fevers (we observed it in one girl with

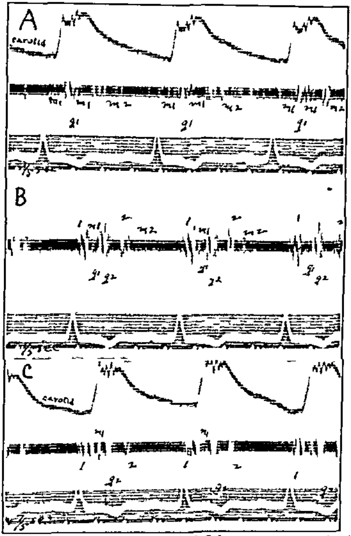

FIGURE 17. Systolic gallop rhythm. *A*, *B* and *C* from same patient. In *A* the sounds were recorded in the first interspace to the right of the sternum. At this position the only conspicuous sound aside from systolic and diastolic murmurs was a loud nearly mid systolic sound (g 1). In *C* at the apex first and second sounds were recorded and also a loud sound (g 2) slightly later in time than the mid systolic sound recorded at the base. In *B* sounds recorded in the fourth interspace just to the left of the sternum show both the aortic and apical systolic gallop sounds (g 1 and g 2), split first and second sounds as well as the systolic (*m* 1) and diastolic (*m* 2) murmurs.

acute miliary tuberculosis), hypertensive cardiovascular disease and aortic insufficiency. The last four cases in which we have discovered systolic gallop rhythm all had aortic insufficiency and it apparently occurs

more commonly in this condition than any other. We were able to obtain a roentgenkymogram of the ascending aorta in one patient with aortic regurgitation and systolic gallop rhythm.[36] It was found that the systolic gallop sound was synchronous with the peak of the systolic expansion of the aorta. It is probable that the sound is due to checking of the expansion of the ascending aorta (as was first suggested by Potain) or to the impact of the expanding aorta against surrounding structures.

A similar sound, heard at the apex in one of our cases with aortic systolic gallop rhythm[36] fell 0.04 second later than the aortic sound and was synchronous with the peak of a positive wave in the apex cardiogram, suggesting that impact of the ventricle against the chest wall as a factor in its production (Fig. 17). We have not as yet observed systolic gallop rhythm in any patient with a normal cardiovascular system.

THE OPENING SNAP OF MITRAL STENOSIS

This sound has been confused by some writers with reduplication of the second sound and by others with gallop rhythm. Duroziez,[37] Guttman,[38] Sansom,[39] and Rouches[40] described it and differentiated it from other heart sounds. It is a short, sharp, snapping or clicking sound, usually occurring 0.07 to 0.13 second after the beginning of the second sound. It is usually heard best in the third or fourth interspace, near the anatomical position of the mitral valve, this position being higher and farther to the right than the usual point of maximum intensity of left-sided gallop sounds. We have made studies of its time relationships to various other cardiac events.[41] It occurs just before the beginning of the diastolic murmur of mitral stenosis (Fig. 18). In contradistinction to the gallop sound, it does not have associated with it a prominent wave in the apex cardiogram, but occurs approximately 0.03 second before the small protodiastolic wave usually present in mitral stenosis. The significant time relationship of the snap in cases having split second sounds is with the aortic component (Fig. 18 C). The interval varies in auricular fibrillation, being shorter after highly premature beats and longer after delayed beats. All available evidence indicates that the sound is due, as both Guttman and Rouches believed, to sudden curtailment of the opening movement of the stenosed mitral valve as the blood flow from the auricle to the ventricle begins in early diastole.

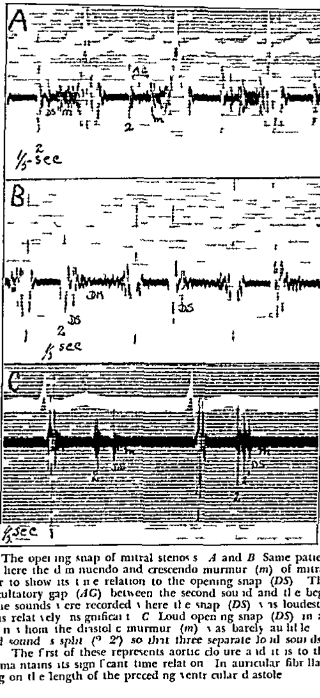

FIGURE 18 The opening snap of mitral stenosis *A* and *B* Same patient *A* Sounds were recorded where the diminuendo and crescendo murmur (*m*) of mitral stenosis was loudest in order to show its time relation to the opening snap (*DS*) The snap occurs during the auscultatory gap (*AG*) between the second sound and the beginning of the murmur *B* The sounds were recorded where the snap (*DS*) was loudest At this area the murmur was relatively insignificant *C* Loud opening snap (*DS*) in a patient with mitral stenosis in whom the diastolic murmur (*m*) was barely audible In the second beat *the second sound is split (2 2') so that three separate loud sounds are heard* in rapid succession The first of these represents aortic closure and it is to this sound that the snap (*DS*) maintains its significant time relation In auricular fibrillation this time varies depending on the length of the preceding ventricular diastole

The opening snap has a practical value in the diagnosis of mitral stenosis second only to that of the characteristic murmur. It is present in well over half the cases and in many it is distinct and easily heard when the murmur is difficult to elicit. Its sharp snapping or clicking quality distinguishes it from all other sounds heard during diastole. Its point of maximum intensity and time relation to the second sound also help to differentiate it from both reduplication of the second sound and protodiastolic gallop rhythm. So far as our experience goes the opening snap occurs only in mitral stenosis. Others have stated that it occurs in aortic insufficiency and adhesive pericarditis. It may be heard in cases of aortic insufficiency in which mitral stenosis is also present but not otherwise. The statement that it occurs in adhesive pericarditis is an error possibly due to confusing the opening snap with the protodiastolic pericardiac vibration of Lian present in some cases with calcified pericardium. The two can be differentiated by the time relations and areas of maximum audibility of the sounds as well as by the fact that the pericardiac vibration has a sharp palpable impulse associated with it.

THE SEMILUNAR OPENING CLICK

We have recently become aware of a sound occurring in early systole which we believe we had previously either overlooked or mistaken for the second component of a split first sound. (Observations to be reported.) The characteristics of this sound are so distinctive that once they are known the sound is easy to recognize. The term semilunar openin click was adopted to call attention to the character of the sound, the area over which it is heard best and its time relations. It is loudest at the base either over the aortic or pulmonic area. When it occurs over the aortic area it can be shown by simultaneously recorded sound and carotid artery tracings to fall within the range of 0.01 to 0.02 second before the primary carotid oscillation (Fig. 19). This means that it is approximately synchronous with the beginning of ejection into the aorta. When the sound is heard best over the pulmonic area the relations to the carotid pulse are not quite so constant but it is probable that in such cases the sound is synchronous with beginning ejection into the pulmonary artery. The sound is short, high pitched and usually clicklike in character. The time of its occurrence is such that grouped with a single first sound the two may resemble a split first sound. How

ever, the click may be present when the first sound is split. Under these circumstances the click in some cases may fall between the two components of the split first sound or in others may follow the second component.

The semilunar opening click is most likely to be found when the heart has extra work to do. Most of our patients in whom this sound was heard over the aortic area had systemic arterial hypertension. In two aortic aneurysm was present. In the patients in whom it was heard

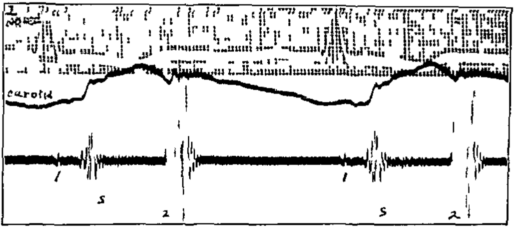

FIGURE 19 The semilunar opening click (s) recorded at the base. At this area the first sound (1) was insignificant. The click was loud and sharp and preceded the carotid upstroke by 0.02 second. The film was run rapidly to display time relations. Each vertical line represents 0.01 second.

best over the pulmonary artery there was dilatation of the pulmonary vessels suggesting pulmonary hypertension. We have heard the sound in several patients with patent ductus arteriosus.

SOUNDS IN WHOSE PRODUCTION THE PRESENCE OF AIR PLAYS A PART

1 *Water wheel Murmur* The best known of this group of sounds is a spectacular churning or splashing noise, the so-called *water wheel murmur* (bruit de la roue hydraulique) or bruit de moulin, heard over the precordial area when both fluid and air are present in the pericardial sac. These sounds may be very loud so that they are audible *some distance from the chest*; more often, however, they can be heard only by applying the stethoscope or ear to the precordial area. The sounds are rarely observed except in dealing with war wounds involving the chest. However, the combination of air and fluid in the left chest

also has been described as producing a splashing sound The presence of air and fluid in the pericardial sac does not necessarily mean that the water wheel murmur will always be present One of us failed to elicit it in a case in which approximately half of a large pericardial effusion was withdrawn and replaced by air

2 Splashing Sound Apparently the combination of a large over active heart and just the proper mixture of gas and fluid in the stomach may also produce a splashing sound with each heartbeat O H Perry Pepper[42] has reported such a case and refers to a similar case previously reported by Spillman and Perrin[43] Pepper recently while making rounds heard a similar sound in a patient with aortic insufficiency and a very large heart The splashing sound in this patient lasted for only a short time and was not heard again during his stay in the hospital This sound has little clinical significance beyond the fact that it should not be confused with the water wheel pericardial murmur

3 The Pericardial Knock This designation has been applied to a knocking or tapping sound heard over the chest usually during the systolic phase of the heartbeat in certain cases with left sided pneu mothorax The term seems inept since so far as is known the peri cardium is not an important factor in the production of the sound According to Barnwell[44] it was first suggested because of the finding of a shell fragment in the pericardium of a patient exhibiting the sound This is also one of the sounds which may be quite loud and heard some distance from the chest The patient is usually quite aware of its presence Scattered case reports are to be found in the older literature Rees and Hughes[45] reported 9 cases with very loud tapping sounds following war wounds of the chest although some of their cases may not have belonged in this group Various explana tions for its mechanism have been offered Barnwell and Greene[44] suggested two possible mechanisms (1) the free diastolic fling of the heart against the left diaphragm over a distended hollow abdominal viscus (2) the uncushioned systolic impact of the heart against the chest wall in cases of left pneumothorax Cooper (observations to be reported) has found that the sound can be elicited in a large proportion of patients in whom left sided pneumothorax has been induced in the treatment of tuberculosis He observed however that it was necessary to place the patients in certain positions of recumbency usually in the left lateral

decubitus, in order to produce the sound It is tremendously influenced by the phase of respiration In studies of some of these patients made with Cooper, we *concluded that impact against the chest wall of the partially collapsed lung, as it is moved with the heart during systole, is responsible for the sound* The lung movement can easily be seen by fluoroscopy Furthermore, this hypothesis fits in well with the influence of position and respiration on the production of the sound

4. *Sounds Due to Mediastinal Emphysema* The most important discussion of this subject is found in the recent paper by Hamman [46]

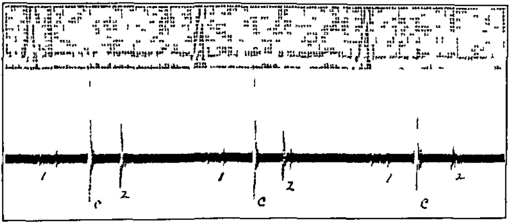

FIGURE 20 Mid systolic short loud crepitating sound (c) in a patient with mediastinal emphysema

It was Hamman s belief that in his cases there was interstitial emphysema of the lungs which traveled to the mediastinum Presumably the cause of the sound is movement of the heart against the emphysematous tissue, with the production of sounds analogous to those produced by the pressure of a stethoscope against subcutaneous emphysema These sounds may be quite loud They are noted by the patient himself and may sometimes be heard across the room Hamman used many adjectives in describing the sound, including such terms as crunching, crackling, crepitating, bubbling, clicking and popping We have observed a similar sound in one patient after perirenal air injection and in another after paravertebral novocain injection of the upper thoracic sympathetics (To be published) In both patients a loud crackling sound was heard during systole (Fig 20), but one case differed from those of Hamman in that at times a similar but less loud

sound could be heard *during diastole. We assumed that in our cases,* air had traveled to the mediastinal space from the sites of injection. In one, air could be demonstrated in the mediastinum by roentgenogram. Mencher,[17] *has recently shown that mediastinal emphysema is not un*common after perirenal air injection. So far as we are aware, this sound has not been observed previously after paravertebral injection. We have been able to duplicate the sound heard in our patients by injecting air into the mediastinal tissues of a dog.

SOUNDS ASSOCIATED WITH AURICULAR CONTRACTION

There are certain sounds due to auricular activity such as auricular friction sounds (observed occasionally in pericarditis) and murmurs (commonest in mitral stenosis) which do not fall within the scope of this discussion. We have discussed previously two effects of auricular contraction on sounds emanating from the ventricles. These are the influence of the As-Vs time relation on the loudness of the first heart sound and the rôle played by auricular contraction on the production of presystolic and summation types of gallop rhythm.

It has long been known that sounds corresponding in time to auricular activity can often be heard in cases of heart block. As long ago as 1897 Pouzin[18] supported the view that these sounds were due to closure of *the auriculoventricular valves following immediately after auricular* contraction.* Gallavardin[49] dissented from Pouzin's view and held that these sounds are analogous to those of gallop rhythm and arise in *the ventricles. He proposed that the auscultatory sign be called* "galop du block."

Lewis,[51] on the basis of phonocardiographic studies, found that there *is sometimes a "double auricular sound." He suggested that the first is* due to contraction of the auricles and tension in its walls and the second due to closure of the auriculoventricular valves following cessation of flow *from auricules to ventricles. When only a single sound is heard,* Lewis suggested that it is due to valve closure. In our experience the double

* Griffith[50] in studying a case of this type, made the further observation that when *auricles and ventricles contracted at about the same time the first heart sound* was likely to be much louder than in other beats. Griffith's observation, apparently not considered important at that time, led eventually to the discovery that the time relations of auricular and ventricular activity exert a powerful influence on the loudness of the first sound even when the cardiac mechanism is normal, a phenomenon which we have discussed in connection with the first heart sound. However, it is clear that the contribution of the auricles to the production of the first heart sound is indirect, due to the effect of auricular discharge on ventricular activity, and not due to sound originating within the auricles themselves.

auricular sound is extremely rare. We have recorded it in only one case. It is possible that the second component of the sound is due to auriculoventricular valve closure. In both Lewis' case and our own, it began approximately 0.30 second after the beginning of the P wave (Fig. 21). However, we have not observed this late sound in the presence of normal rhythm,* although we have recorded it as a single auricular sound in cases of heart block.

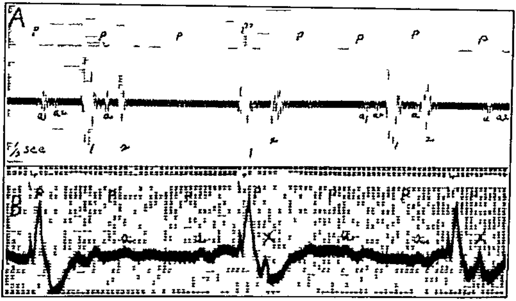

FIGURE 21. *A*. "Double auricular sound" (*a* 1, *a* 2) in complete heart block. When auricular contraction falls during ventricular contraction an extra sound (*a*) is recorded having the same time relation to the P wave as the first component (*a* 1) of the double sound. *B*. Apex cardiogram. Same patient. (The P waves in the electrocardiogram can barely be seen due to failure to loosen and standardize the string.) When, however, the auricles beat during certain phases of ventricular systole an extra wave (*x*) may be seen in the apex cardiogram much larger than waves caused by auricular contraction during ventricular diastole (*a*). We interpret these large waves as indicating that auricular contraction was moving the ventricle as a whole against the chest wall. During diastole when the ventricular wall is flaccid no such wave is found but only small waves of filling.

The first component is apt to fall 0.08 to 0.14 second after the beginning of the P wave, as is the case in presystolic gallop rhythm. It is probably not due to A-V valve closure. We have pointed out previously in this discussion that presystolic gallop sounds precede that event. In both Lewis' and our case of heart block a sound having the same time relation to auricular activity as this first component, was heard and recorded even during the ejection period of ventricular systole (Fig. 21).

* If due to A-V valve closure, it could not occur when the P-R interval is normal, since the valve would already be closed by ventricular contraction.

Characteristics of the so-called auricular sound, which falls in the range of 0.08 to 0.14 second after the beginning of the P wave in cases of heart block, are as follows: (1) It is likely to be much louder when it is superimposed on early ventricular filling than at any other time (in this respect behaving like summation gallop). (2) It is low-pitched. (3) It is heard best near the apex. All these findings, together with its time relations, support Gallavardin's view that it is a form of gallop rhythm and that, although the sound results from auricular activity, it actually arises in the ventricle. Such an explanation, however, does not account for the sound heard during ventricular systole. In our case this sound, like the first component during diastole, was also heard best at the apex. An apex cardiogram and a roentgenkymogram of the left ventricular border both showed a wave whose peak was simultaneous with the sound. In the former, the auricular wave during ventricular systole was very prominent (Fig. 21 *B*). We concluded, therefore, that auricular systole, occurring during ventricular systole, pushed the contracting ventricle against the chest wall causing impact and producing sound.

One may raise the question as to why "galop du block" should be relatively commoner in cases of heart block than is presystolic gallop rhythm in cases with a normal cardiac mechanism. We have been much impressed by the rapidity and extent of ventricular dilatation which may develop when complete heart block replaces normal sinus rhythm One possible mechanism is that, under such circumstances, the thickness of the ventricular wall must be decreased so that a wave of ventricular filling caused by auricular systole would result in less absorption of the impact in the ventricular wall (and therefore more transmission to the chest) than would be the case if that wall were thicker. Furthermore, in cases of heart block with slow ventricular rate, ventricular systole is prolonged so that in early diastole the auricles are likely to be engorged with blood If auricular contraction comes at such a time it is apt to augment greatly the wave of the early diastolic filling, a circumstance which would be favorable to the production of sound.

In some cases of heart block, a sound associated with auricular activity is heard best in the third or fourth interspaces and not at the apex. So far as we are aware, these sounds have not been carefully studied but they may be the same as the second component of the double

TABLE I

EXTRA SOUNDS ASSOCIATED WITH THE HEARTBEAT AND SOME OF THEIR CHARACTERISTICS

	Point of Maximum Intensity	*Time Relation*	*Character*	*Remarks*
Reduplicated first sound	Apex or just to left of lower part of sternum	Interval 0.04 to 0.12 second	Both sounds similar altho one may be louder than the other	Easily differentiated by the time relations from all extra sounds except late presystolic gallop and semi lunar opening click. Common in both healthy and diseased hearts
Semi lunar opening click	Aortic or pulmonic area	Synchronous with beginning of ventricular ejection	Sharp clicking or snapping	Differentiated from reduplication of the first sound by area of maximum intensity. Rare
Mid systolic click	Inside apex fourth or fifth interspace	Between first and second sound. Often varies with respiratory phases	Sharp snapping or clicking sound	No clinical importance. Must be differentiated from apical systolic gallop rhythm. Fairly common. No pathological significance
Systolic gallop	Aortic area or apex	Constant and about midway between the first and second sound	Medium pitch. May be loud or faint	The aortic type is distinctive. The apical type must be differentiated from the mid systolic click. Rare
Pericardial knock	At apex or to left of heart	Inconstant. Usually systolic but may also have diastolic component	Knocking. May be very loud	Occurs in cases with air in left pleural space. Can often be elicited after left sided pneumothorax
Sounds due to mediastinal emphysema	Precordial area	Usually systolic. May have diastolic component	Snapping or crunching. May be very loud	May follow spontaneous pneumothorax or perirenal air injection. Resembles the pericardial knock. Rare
Sounds due to agitation of air and fluid in stomach by the heart beat	Lower precordium and epigastrium	Systolic and diastolic	Splashing sounds	Appears to require for its production large overactive heart as well as the appropriate combination of air and fluid in the stomach. Extremely rare
Reduplicated second sound	Base	Interval 0.03 to 0.11 second	Both sounds usually have similar character altho one may be louder or higher pitched than the other	Must be differentiated from the opening snap. Common in both healthy and diseased hearts

TABLE I (Continued)

Extra Sounds Associated With the Heartbeat and Some of Their Characteristics

	Point of Maximum Intensity	*Time Relation*	*Character*	*Remarks*
The opening snap	Just below mitral ring third or fourth interspace	0.07 to 0.13 second after second sound	Sharp snap or clicking sound. Loud or faint	Must be differentiated from reduplication of the second sound. Common in mitral stenosis and pathognomonic of this lesion
Physiological third heart sound	Inside apex usually fourth interspace	0.12 to 0.18 second after second sound	Usually faint low pitched	Cannot be distinguished from gallop except by absence of heart disease. Common in youth
Protodiastolic gallop	Inside apex usually fourth or fifth interspace	0.12 to 0.20 second after second sound	Usually faint low pitched	Cannot be distinguished from physiological third heart sound except by presence of heart disease. Common in diseased or failing hearts
Presystolic (auricular systolic) gallop	Inside apex usually fourth or fifth interspace	0.08 to 0.14 second after beginning of P	Usually faint low pitched	Ability to time it before the first sound is most important differential point. Common in diseased or failing hearts
Summation form of gallop	Inside apex usually fourth or fifth interspace or just to left of sternum	Usually 0.12 to 0.20 second after second sound	Low-pitched may be faint loud or short murmur	The rate usually exceeds 100 beats per minute unless delayed conduction is present. Occurs when auricular systole falls close to preceding ventricular beat. Common in diseased or failing hearts
Protodiastolic pericardiac vibration	Precordial	Usually 0.12 to 0.20 second after second sound	Strong vibrating sound	Louder than normal heart sounds. Differentiated from protodiastolic gallop and physiological third heart sound by its constancy and greater strength from the opening snap by greater intensity and longer interval after the second sound. Pathognomonic of pericardial calcification
Auricular Sounds Early Type	Apex	0.08 to 0.14 second after beginning of P wave	Low pitched	Heard in heart block. Similar to presystolic gallop
Late Type	Third or fourth interspace	0.24 to 0.30 second after beginning of P wave	Low pitched	Heard in heart block. Mechanism not known

auricular sound Their position suggests that they might be due to A V valve closure It seems to us unlikely that they are due directly to contraction and tension of the auricular walls but this possibility has not been excluded

The problem of auricular sounds needs further study particularly in cases of complete heart block On the basis of evidence available at present it is clear that at least two and probably three different mechanisms may produce so-called auricular sounds The earlier of the two auricular sounds which may be heard during ventricular diastolic periods in heart block resembles presystolic gallop sounds so closely that it like presystolic gallop is almost certainly caused by the effect of auricular contraction on the wave of ventricular filling The later auricular sound which has been observed only in cases of heart block may be due to auriculoventricular valve closure The auricular sound noted during ventricular systole cannot be due to either of these mechanisms The limited observations made suggest that it is due to the effect of auricular contraction in pushing the contracting ventricle against the chest wall The question as to whether auricular contraction and tension of its walls produces sound which can be heard by the stethoscope remains open

The accompanying table (Chart I) points out characteristics tending to differentiate these extra or additional sounds

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CHAPTER XXVII

FORM OF THE ELECTROCARDIOGRAM

By Frank N Wilson M D

Introduction This chapter is devoted to a consideration of the significance of the form of the electrocardiogram Inasmuch as the cardiac irregularities are discussed elsewhere in this volume no reference is made here to alterations in the contour of the electrocardiographic deflections which depend upon changes in the site or mechanism of impulse formation or the like or upon excessive acceleration of the heart rate such as occurs in auricular flutter and paroxysmal tachycardia In discussing the ventricular complex it is assumed throughout that the ventricles are responding to stimuli of supraventricular origin

I NORMAL ELECTROCARDIOGRAM

In taking clinical electrocardiograms it is the universal custom to employ the three standard leads originally adopted by Einthoven In Lead I the galvanometer terminals are attached to the right arm and left arm *in Lead II to the right arm and left leg in Lead III to the* left arm and left leg In each case the connections are made in such a way that relative negativity of the first named extremity will produce an upward deflection in the completed record The sensitivity of the galvanometer is so adjusted that a difference in potential of one millivolt is represented in the record by a deflection of one centimeter

A typical example of the curves obtained from normal subjects is shown in Fig 1 *Although all of the leads depict the same series of* events they differ considerably in detail In each lead the heartbeat is represented by a group of summits and depressions as many as 6 distinct deflections P Q R S, T and U may occur In normal curves the summits P R and T are always present but either or both of the depressions Q and S may be absent and conspicuous U deflections are rarely

seen. The first deflection, P, is associated with auricular systole and is often referred to as the *auricular complex;* Q, R, S, and T are ascribed to ventricular events and constitute the *ventricular complex;* U occurs in early diastole and is of unknown origin.

No entirely satisfactory statistical study of the variations in size normally displayed by the different electrocardiographic deflections has as yet been made.

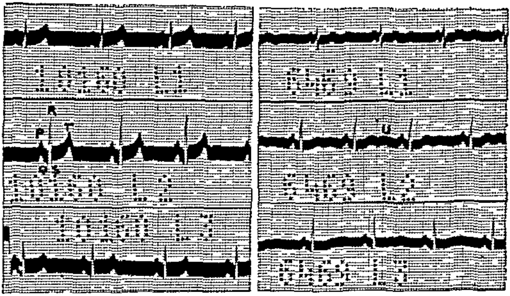


FIGURE I No 10160 Normal electrocardiogram The effect of introducing a potential difference of one millivolt into the circuit containing the patient and the galvanometer is shown at the left end of Lead III In this curve and in those which follow a potential difference of one millivolt is represented by a deflection of one centimeter The vertical lines which cross the record mark intervals of 0 04 and 0.20 second. No 6469 A normal electrocardiogram showing a prominent U deflection. (Cyclopedia of Medicine, F. A. Davis Co)

The data presented in Table I are taken from a study by Wilson and Nyboer[1] based upon measurements of the electrocardiograms of 104 healthy young men, most of whom were between 20 and 30 years of age. This table gives the mean, the standard deviation and the skewness of each of the frequency distributions obtained by measuring (*a*) the voltage of the P, Q, R, S, and T deflections and of R plus S in each of the standard limb leads; and (*b*) the axis deviation index obtained by the formula $(R_1 - S_1) - (R_3 - S_3)$ in which R_1 is the voltage of R in Lead I and the other symbols have a similar significance. These statistical constants when used in connection with suitable tables make it possible

to predict how frequently each of these deflections will reach or exceed a given voltage in the electrocardiograms of normal subjects. The last four columns of the table give the values of each variate which, it is predicted, will not be exceeded more often than once in a hundred, once in a thousand, once in ten thousand, and once in a hundred thousand observations, respectively. These predictions refer, of course, to curves of the kind upon which the original study was based, the electrocardiograms of normal men in the third decade of life. In addition to the data already mentioned the table gives the minimum and maximum observed values of each variate. All of the voltages given in the table are expressed in millimeters or tenths of a millivolt.

Certain features of Table I require further explanation. The statistical tables available give no data for frequency distributions with a skewness greater than 1.1. In four instances the computed value of the skewness exceeds this figure; in the case of Q_1 it is 1.25; in the case of R_1 it is 1.56; in the case of S_3 it is 3 37 and in the case of $(R+S)_1$ it is 1.35. The first of these large values is apparently a consequence of the absence of Q_1 in 50 of the 104 electrocardiograms of the series studied The second is due to the occurrence in one of the electrocardiograms of an R_1 which measured 19 4 mm. The elimination of this very unusual curve reduced the maximum observed height of R_1 to 12.0 mm. and the skewness of the distribution to 0.73 Another electrocardiogram displayed a striking degree of left axis deviation with S_2 deflections of 8 mm and S_3 deflections of 13 mm Although careful examination of the subject from which this curve was obtained showed no clear evidence of heart disease, it was suspected that it was abnormal. When it was dropped from the series the largest S_3 remaining measured only 4 5 mm and the skewness for S_3 fell to 0.67. In the case of S_2 the maximum amplitude fell to 6 mm and the skewness to 0.59. It may be pointed out that relatively few observations will give a fairly accurate estimate of the mean, a larger number are needed to obtain an equally accurate estimate of the standard deviation, which is based upon the squares of the deviations of the individual variates from the mean; and a far larger number are needed to obtain an accurate estimate of the skewness which is based upon the cubes of the deviations from the mean. It will be noted that casting out the largest variate in the instances mentioned had a much greater effect upon the skewness than upon the other statistical constants. In order to

TABLE I

	Mean	*Stand Dev*	*Skew*	*Min*	*Max*	*1 per cent*	*0.1 per cent*	*0.01 per cent*	*0.001 per cent*
P_1	0.50	0.21	0.87	0	1.2	1.12	1.42	1.70	1.97
P_2	1.15	0.40	0.56	0.3	2.5	2.25	2.73	3.17	3.58
P_3	0.77	0.39	0.23	0.2	1.8	1.81	2.09	2.39	2.66
Q_1	0.36	0.45	1.25	0	2.0	1.75	2.46	3.14	3.81
Q_2	0.58	0.59	1.02	0	2.5	2.36	3.25	4.09	4.91
Q_3	0.61	0.66	1.12	0	3.0	2.64	3.69	4.69	5.67
R_1	5.73 5.60	2.74 2.40	1.56 0.73	1.5 1.5	19.4 12.0	14.20 12.36	18.53 15.44	22.66 18.25	26.72 20.91
R_2	11.90	3.96	0.43	4.0	23.6	22.28	26.43	30.12	33.48
R_3	7.99	4.41	0.37	1.0	20.0	19.54	24.17	28.28	32.02
S_1	1.78	1.27	0.61	0	6.0	5.29	6.81	8.19	9.49
S_2	1.83 1.77	1.52 1.40	1.00 0.59	0 0	8.0 6.0	6.42 5.63	8.72 7.31	10.87 8.84	12.99 10.27
S_3	1.39 1.28	1.67 1.23	3.37 0.67	0 0	13.0 4.5	6.55 4.75	9.19 6.32	11.71 7.76	14.18 9.13
T_1	2.05	0.97	0.94	−0.5	5.5	4.92 0.44	6.31	7.61	9.17
T_2	2.99	1.37	0.30	0	8.0	6.47 0.10	7.81	8.98	10.05
T_3	1.22	1.22	0.30	−2.0	5.5	4.31 −1.34	5.51	6.55	7.50
$(R + S)_1$	7.58	2.94	1.35	2.5	20.6	16.66 3.11	21.31 2.64	25.75 2.43	30.10 2.28
$(R + S)_2$	13.88	3.63	0.58	6.0	25.4	23.90 7.05	28.25 5.63	32.21 4.70	35.91 4.04
$(R + S)_3$	9.68	4.27	0.51	3.2	18.0	21.17 1.35	25.95	30.26	34.28
Index	−2.68	6.70	0.31	−17.2	20.5	14.34 −16.75	20.90 −20.57	26.60 −23.45	31.83 −25.73

(Wilson Assoc Life Insurance Medical Directors of America)

obtain entirely reliable values for the skewness many more observations than were available would have been required

These considerations explain the double entries corresponding to R_1 S_2, and S_3 The first entry is based upon the complete series the second shows the effect of dropping the largest variate The predictions of the last four columns were computed from the data given in the statistical tables for a skewness of 1.1 in those instances where the estimated value of the skewness exceeded this figure In the case of the axis deviation index of $(R+S)_2$ and of T_1 T_2 and T_3 double entries appear in the last four columns only the two figures give two values of the variable the first greater and the second less than the mean which may be expected to be equally rare

It may be mentioned here that the standard deviation is a measure of the dispersion of variates about the mean or in other words of the variability of the quantity under consideration The skewness is a measure of the asymmetry of the distribution When the skewness in zero variates which are greater and those which are less than the mean and differ from it by a given fraction or multiple of the standard deviation are equally common Under these circumstances only one per cent of the variates exceed the mean by more than 2.33 times the standard deviation and deviations from the mean of the same magnitude but in the opposite direction are equally rare

In electrocardiography as in other fields it is not possible to draw a sharp line between the normal and the abnormal In reaching a decision as to the possible abnormality of a given finding we must depend upon a conscious or unconscious estimate of the probability of its occurrence in the electrocardiogram of a normal subject Statistical tables of the kind under consideration are a far better guide than the rather vague and changeable impressions that we gain from experience In using such a table we must of course decide how uncommon in normal curves a given finding must be before the probability that it is abnormal in a given instance approaches certainty It would seem that a finding which may be expected to occur in less than one per cent of normal electrocardiograms should be regarded as probably abnormal and one that may be expected to occur in less than one tenth of one per cent of normal electrocardiograms should be regarded as almost certainly abnormal

Since the study outlined was based upon the electrocardiograms of young men between 20 and 30 years of age the conclusions derived from it cannot be applied without reserve to the electrocardiograms of subjects of the opposite sex or to the electrocardiograms of those who fall in an earlier or later decade of life than the third. We are in urgent need of a more comprehensive statistical study of a large series of electrocardiograms obtained from normal subjects of both sexes and of all ages.

For most purposes P waves measuring 2.5 mm., R waves measuring 20 mm., and T waves measuring 5 mm., occurring in electrocardiograms so standardized that a *deflection of one centimeter represents a potential difference of one millivolt*, may be regarded as near the upper limits of normality. It is customary to consider electrocardiograms in which the largest deflection in any lead is less than 5 mm. as of abnormally small voltage. When the Q deflection in Lead III is more than one fourth as large as the largest deflection in any lead, its normality is considered questionable.

The auricular deflection, P, is the graph of the electrical effects produced by the spread of the excitatory process over the auricular muscle. It is normally a small, rounded or slightly pointed summit in Leads I and II. It is usually a summit in Lead III as well; in this lead, however, it may be partially or completely inverted. It is occasionally notched near the apex.

The interval which separates the beginning of P from the onset of the deflection which follows it, the P-Q or P-R interval as the case may be, is a measure of the time which elapses between the beginning of auricular and the beginning of ventricular systole. In normal adults it varies in duration from 0.12 to 0.20 second.

The initial ventricular deflections, Q, R, and S are attributed to the activation of the ventricular muscle; it has been shown that all of the ventricular muscle passes into the excited state during the period within which these deflections are inscribed.[2] The Q-R-S interval, measured from the beginning of Q to the end of S, does not normally exceed 0.10 second in duration. In many normal electrocardiograms the initial ventricular deflections of Lead III are small and bizarre in form, and show conspicuous notching and splintering. In abnormal electrocardiograms it is often impossible to distinguish between Q, R, and S, *and it is not desirable to*

do so except for purposes of description, because electrical events which are represented by an upstroke in one lead may be represented by a downstroke in another.

In normal curves the final ventricular deflection, T, is always directed upward in Lead II and, except in very rare instances, in Lead I. It is fre-

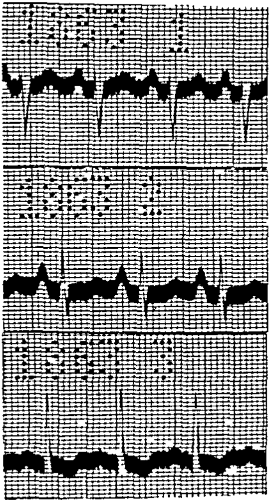


FIGURE 2. Electrocardiogram of a patient with high grade mitral stenosis. The P summits are very tall and broad in *Leads I and II*. The curve also shows right axis deviation. (Cyclopedia of Medicine, F. A. Davis Co.)

quently inverted in Lead III. This deflection is ascribed to the deactivation of the ventricular muscle, in other words, to the decline of the excited state or to a reversal of the process which is responsible for the initial ventricular deflections. In order to account for the fact that the duration of T is much greater than the duration of Q R S, it is assumed that deactivation takes place much more slowly than activation.

II ABNORMALITIES OF THE AURICULAR COMPLEX

The form of the auricular complex may be altered by a change in the site of impulse formation by a change in the course of the excitation process over the auricular muscle by a change in the mass or distribution of the auricular muscle or by a change in the position of the heart The deviations from the normal apart from those associated with the cardiac arrhythmias are only occasionally of diagnostic importance In advanced mitral stenosis the P deflections are often very large (Fig 2) and broad and show pronounced notching or other peculiarities of form White and Burwell[3] have called attention to the fact that large auricular deflections are common in congenital heart disease In sinus tachycardia the P deflections may be unusually tall but their breadth is not conspicuously increased nor are they altered in other respects Inversion of P in Lead III may occur in normal individuals inversion in Leads II and III (Fig 3) is almost always associated with some shortening of the P R interval and is due to atrioventricular rhythm in which the atrioventricular node has taken over the function of cardiac pacemaker In situs inversus viscerum all of the deflections of Lead I are inverted When the heart is in the normal position inversion of P in Lead I is rare and is probably always due to myocardial changes which interfere with the spread of the impulse over the auricular muscle

III THE P R INTERVAL

With very rare exceptions of which the cause is unknown abnormally short P R intervals are always associated with inversion of the P waves in Leads II and III and are due as noted above to atrioventricular rhythm

When the P R interval exceeds 0 20 second (Fig 4) there is a defect in conduction *between the auricular border of the atrioventricular node* and the bifurcation of the His-bundle the defect may be temporary or permanent Such a disturbance may occur in almost any form of heart disease As a temporary phenomenon it is particularly common during the course of rheumatic infections it occurs less often in other acute infectious diseases An abnormally long P R interval may be produced in normal individuals by the administration of adequate doses of digitalis (Fig 14) A permanent increase in the P R interval is common in rheumatic luetic and arteriosclerotic heart disease It is rare in thyrotoxic *heart disease A long P R interval is often associated with presystolic* gallop rhythm

IV. THE Q-R-S INTERVAL

It has been pointed out that all of the ventricular muscle passes into the excited state during the inscription of the initial deflections of the ventricular complex. The length of the Q-R-S interval may, therefore, be regarded as a measure of the efficiency of the intraventricular conducting system; an increase in this interval beyond the upper normal limit of 0.10 second must be ascribed to a defect in conduction below the

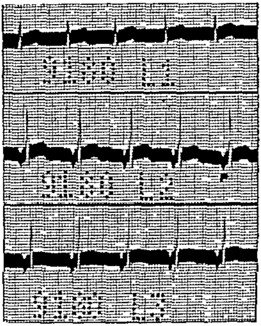


Figure 3 *Inversion of the P deflection in Leads II and III with slight shortening of the* P R interval Atrioventricular rhythm (Cyclopedia of Medicine, F A Davis Co)

bifurcation of the His-bundle. It is obvious that at points where the path of the excitation wave is narrow, it may be obstructed by a small area of impaired conductivity; where the path is wide, it is much less easily blocked. For this reason a small lesion which involves one of the main *branches of the His bundle may* produce a conspicuous *increase in the* Q-R-S interval and a profound change in the form of the ventricular complex, while lesions which involve the Purkinje network must be extensive *if they are to give rise to alterations of a similar grade.* Toxic *influences,* unlike discrete structural lesions, may depress the conductivity of the ventricular conducting system as a whole. There is at the present time no evidence that lesions which involve only the ordinary ventricular mus-

cle can give rise to a measurable increase in the duration of the initial deflections. Ventricular hypertrophy, by increasing the thickness of the ventricular walls, and, therefore, the length of the path through ordinary ventricular muscle which the excitation process must pursue, undoubtedly increases the length of the Q-R-S interval; but the evidence bearing upon this problem seems to indicate that an increase in this interval beyond 0.10 second is seldom due to this cause.[4]

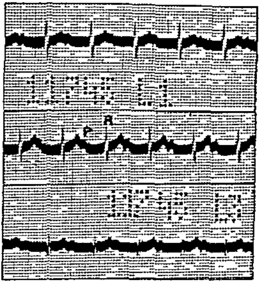


FIGURE 4 Electrocardiogram of a patient with an acute infection, possibly atypical rheumatic fever. The P R interval is greatly increased in length and measures approximately 0.32 second. (Cyclopedia of Medicine, F A Davis Co)

Since the electrical axis may be perpendicular to one of the three leads either at the beginning or at the end of the Q-R-S interval, the length of this interval may not be the same for all leads. When this is the case, the longest interval, or the mean of the two longest intervals, should be taken as the true value.

The broad term *intraventricular block* is applied to all those conditions in which the Q R-S interval is definitely greater than 0.10 second. *According to the location of the conduction defect, when this can be* ascertained, several varieties of intraventricular block may be distinguished. *When the conduction defect completely interrupts the passage* of the cardiac impulse through one of the two main branches of His bundle, the Q-R-S interval ordinarily measures 0 12 second or more and the form of the ventricular deflections is usually sufficiently distinctive to

permit a diagnosis of *complete bundle branch block,* right or left as the case may be, to be made with confidence. *Incomplete bundle branch block,* due to conduction defects which merely retard the passage of the impulse through one of the main bundle branches, gives rise to electrocardiograms which are of less distinctive character and are transitional, both as regards the length of the Q R S interval and the form of the ventricular deflections, between those which represent complete bundle branch block and electrocardiograms of normal outline.[5]

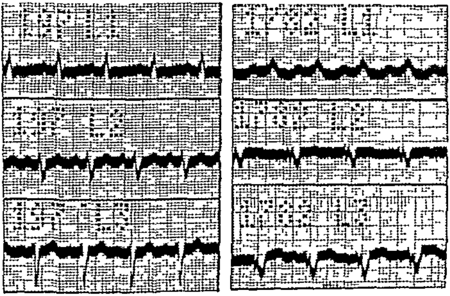


FIGURE 5 Electrocardiograms of two patients who showed post mortem, extensive lesions involving the endocardium and subendocardial tissues on the left side of the ventricular septum The ventricular deflections are of relatively small amplitude and the Q R S interval is increased These cases (particularly No 1782) belong to the group described by Oppenheimer and Rothschild as examples of arborization block, both from the electrocardiographic and the pathologic standpoint. (Cyclopedia of Medicine F A. Davis Co)

The term *arborization block*[6] is often applied to cases in which extensive involvement of the subendocardial tissues of the ventricular septum, particularly on the left side, is suspected, but the criteria upon which this diagnosis should rest are less well-defined than in the case of bundle branch block and are not generally agreed upon. The writer believes that most of the cases which are classified as arborization block are really examples of bundle branch block, complete or incomplete, in which the electrocardiogram is somewhat atypical because of the presence of intraventricular defects in conduction other than those affecting the bundle

branch involved, of peculiarities in the position of the heart, of preponderant enlargement of the one or the other ventricle, of myocardial infarction, of cardiac failure or of some combination of these

In many cases of intraventricular block, present knowledge does not enable the clinician to determine what portion of the intraventricular conducting system is involved

Intraventricular block may be transient or permanent even when it is transient, there is often reason to suspect the presence of an underlying, more permanent change in the ventricular muscle In comparison with atrioventricular block it is seldom produced by drugs Quinidine because of its depressing effect upon the intraventricular conducting system often increases slightly the length of the Q R S interval, when given in large doses in cases in which the heart rate is greatly accelerated it may produce profound changes Instances in which intraventricular block can be ascribed to the administration of large doses of digitalis are rare A few cases of intraventricular block associated with a very short P R interval and with attacks of paroxysmal tachycardia in which the block could be temporarily abolished by the administration of atropine, have been described [7] Some of these patients have shown no other evidence of heart disease but the writer has seen an instance of this kind in which extensive fibrosis of the myocardium was found post mortem

High grade intraventricular block frequently occurs in association with the severe myocardial changes which sometimes follow diphtheria Lesser grades may occur during the course of rheumatic infections Intraventricular block is occasionally seen in congenital heart disease, particularly when the ventricular septum is incomplete It is not uncommon in mitral stenosis It is seen most often, however, in luetic and in arteriosclerotic heart disease especially in those cases in which there is involvement of the coronary arteries It is frequent and usually of serious import in coronary thrombosis It sometimes occurs in uremia here it may be due to the depressing effect of the toxemia upon the conductivity of the special tissues

The recognition of intraventricular block is of clinical importance chiefly because it enables one to say that the myocardium has been attacked by some disease process the nature of this disease process cannot be determined from the form of the ventricular complex it must be judged from all of the clinical data available Insofar as it adds in this

way to information regarding the patient, the presence of intraventricular block may help in making a more accurate diagnosis and prognosis; no final conclusion should be based upon the electrocardiogram alone.

V. THE Q-T INTERVAL

The duration of electrical systole, measured from the beginning of Q-R-S to the end of T, varies with the heart rate. Various formulae which express this relation have been devised. Bazett's formula, (Q-T) interval $= K \sqrt{}$ (R-R) interval, where K is a constant, has been widely used. According to Cheer and Li,[8] the average value of K for normal males is 0.374 (standard deviation, 0.0129), and for normal females it is 0.388 (standard deviation, 0.0166). Up to the present time, the length of the Q-T interval has not proved to be of much diagnostic importance. Striking prolongation of this interval without a corresponding increase in the duration of mechanical systole occurs when the blood calcium falls to a very low level in hypoparathyroidism or in nephritis. Prolongation of this interval has also been observed in bundle branch block, in complete A-V heart block, in coronary occlusion accompanied by very large inverted T deflections, and in cardiac failure. Cheer and Dieuaide[9] observed a decrease in the Q-T interval after the administration of digitalis.

VI. EINTHOVEN'S LAW AND TRIANGLE

Many years ago Einthoven[10] pointed out that the three standard leads are so related to each other that at any instant the sum of the deflections in Lead I (e_1) and in Lead III (e_3) must equal the deflection in Lead II (e_2). He expressed this relation in the form of a simple equation:

$$e_1 + e_3 = e_2$$

which has been referred to as *Einthoven's law*. Because the significance of this equation has frequently been misunderstood, it seems desirable to call attention to the considerations upon which it is based.

In taking a standard electrocardiogram, the galvanometer is so adjusted that with the patient in the string circuit a difference of potential of one millivolt produces a deflection of one centimeter. Consequently, the instrument measures the magnitude of the potential difference between the two extremities to which it is attached. If the potential of

the right arm at any instant is represented by V_R, that of the left arm by V_L, and that of the left leg by V_F, then clearly:

$$e_1 = V_L - V_R$$
$$e_2 = V_F - V_R$$
$$e_3 = V_F - V_L$$

and

$$e_1 + e_3 = V_L - V_R + V_F - V_L = V_F - V_R = e_2$$

which is Einthoven's law.

It is true that the attachment of the galvanometer, of which the resistance is not infinite, alters the potential difference between the points to which its terminals are attached, but this does not invalidate the law, for, as Einthoven[11] pointed out, the method of standardization is such that the small decrease in the potential difference between two extremities which results from connecting them to the galvanometer terminals has no effect upon the record. The electrocardiogram is a record of the potential difference that would have been present had the galvanometer not been attached. Einthoven's law is, therefore, neces sarily true, it serves merely as a check upon the accuracy of the records. Any three points may be substituted for the right arm, left arm, and left foot without interfering with the application of this equation.

It may be pointed out that Einthoven's law does not state that the amplitude in Lead II of a deflection designated by a given letter must equal the sum of the amplitudes of the deflections designated by the same letter in Leads I and III.

In many normal and in most abnormal electrocardiograms a given deflection does not reach its maximum amplitude in all three leads at the same instant, the peaks are not in phase, and simultaneous points cannot be identified unless equipment for taking two leads at the same time is available For such points Einthoven's equation must hold if the curves have been properly taken

In 1913 Einthoven, Fahr and deWaart[12] published a method by means of which it is possible to determine the "manifest" value and direction of the resultant electromotive force produced by the heart at any instant. This method is based upon the laws which govern the distribution of electric currents within nonlinear conductors. Since the two legs are at all times at nearly the same potential, the three extremi ties from which the standard leads are made may be represented by the apices of an equilateral triangle (Fig. 6). At the center of this tri-

angle lies the heart (H). It is assumed that the triangle is composed of material which is homogeneous with respect to its electrical properties. The direction of the resultant electromotive force produced by the heart at any instant, the so-called instantaneous electrical axis, is represented by an arrow which points from the negative toward the positive pole. *It is assumed that the distance between these poles which lie within the* heart, represented by the point (H), is very small in comparison with the distance of the apices of the triangle from its center. The "manifest" magnitude (E) of this electromotive force is represented by an arbitrary segment (P Q) of the shaft of the arrow. Under these circumstances, the difference in potential between any two apices of the triangle must be represented by the projection of P Q upon the line which joins them. In Fig. 2, therefore

$$e_1 = P_1\ Q_1 = E \cos \alpha$$
$$e_2 = P_2\ Q_2 = E \cos (\alpha - 60)$$
$$e_3 = P_3\ Q_3 = E \cos (120 - \alpha)$$

It will be noted that $e_1 + e_3 = e_2$; in other words, these equations are consistent with Einthoven's law. This law is not, however, derived from them.

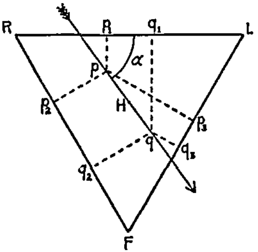
It is apparent that if the deflections in the three leads at any instant, e_1, e_2, e_3, are known, *the value of the angle* α *and of* E *may be determined* by means of the relations

$$\tan \alpha = \frac{e_2 + e_3}{\sqrt{3}\,(e_2 - e_3)}$$
$$E = e_1 \sec \alpha$$

by geometrical construction, or by making use of suitable tables which *have been prepared for the purpose.*

As Einthoven[12] clearly pointed out, the application of this method to the analysis of the electrocardiogram involves certain assumptions; *i. e.*, that the tissues of the body are homogeneous with respect to their electrical *conductivity; that the three extremities used,* or rather the attachments of these extremities to the trunk, are equidistant from all parts of the heart which produce electromotive forces, and that they are situated at the apices of an equilateral triangle. Obviously, these assumptions are not strictly in accord with the facts, but the errors which they introduce are apparently too small to invalidate the method for practical purposes.

It should be noted that in this method the 'manifest' electromotive force is treated as a vector. An electromotive force within a three dimensional conductor can be so treated in this special case and in no other. Einthoven's law holds for any triangle whatsoever, but the method of determining the electrical axis here described holds only in case the leads employed form the sides of an equilateral triangle, with the heart at its center. It may be pointed out also that electromotive forces which lie perpendicular to the plane of the three leads produce no effect upon



$$pq = E$$
$$p_1q_1 = e_1 = E\cos\alpha$$
$$p_2q_2 = e_2 = E\cos(\alpha-60)$$
$$p_3q_3 = e_3 = E\cos(120-\alpha)$$

FIGURE 6 (After Einthoven Fahr and deWaart) Einthoven's equilateral triangle. The deflections in the three standard leads are represented by e_1 e_2 and e_3 respectively The manifest potential difference is represented by E. (Cyclopedia of Medicine F A Davis Co)

them Effects which do not lie in this plane have an effect proportional to the cosine of the angle which they make with it

This method of analysis has proved to be of great value in the solution of many electrocardiographic problems By determining α, which defines the position of the electrical axis, and E the manifest potential difference at the instant when R was inscribed in normal subjects at the end of deep inspiration and also at the end of expiration Einthoven and his collaborators showed that the changes in the amplitude of this deflection produced by the respiratory movements are due to rotation

of the heart about a dorsoventral axis The associated changes in P and T although due in the main to the same cause were found to result in part from fluctuations in vagal tone for these waves unlike R showed a change in E as well as α

In the same article it was also shown that when the three leads are charted on cross section paper one above the other so that simultaneous points fall on the same vertical line it is possible to determine α and E at intervals of 0 01 second or less throughout any desired portion of the cardiac cycle

It has recently been shown[13] that if the assumptions upon which *Einthoven s triangle is based are valid the sum of the potentials at the three apices* produced by the heartbeat at a given instant must be *equal to zero i e*

$$V_R + V_L + V_F = 0$$

It follows that if a central terminal is connected through large and equal noninductive resistors to electrodes placed upon the right arm left arm and left leg the potential of this terminal will not be affected by the heartbeat and may be regarded as zero throughout the cardiac cycle By connecting one of the electrocardiographic lead wires to this indifferent point and the other to an exploring electrode a unipolar lead is obtained The curve so recorded represents the potential variations produced by the heartbeat over that small portion of the body surface with which the exploring electrode is in contact Since it is conventional to plot positive values of the variable above and negative values below the time axis the galvanometer connections should be made in such a way that the trace lies above the base line when the exploring electrode is electrically positive and below the base line when this electrode is electrically negative with respect to the indifferent terminal

The deflection in Lead I at a given instant (E cos α) gives the horizontal component of *the vector which represents the instantaneous electrical axis of the heart* It may be easily shown that the simultaneous deflection in a lead from *the left leg to the indifferent central terminal* represents the vertical component of this vector divided by the square root of three By placing Lead I (amplified 25 000 times) on the horizontal plates and this leg terminal lead (amplified 25 000$\sqrt{3}$ times) on the vertical plates of a cathode ray oscillograph a trace is obtained which gives the position and magnitude of this vector at every instant

throughout the cardiac cycle[14] Some years ago traces of this kind were computed by Mann,[15] who referred to them as monocardiograms The writer prefers to call them vectorcardiograms A normal vectorcardiogram is reproduced in Fig 7.

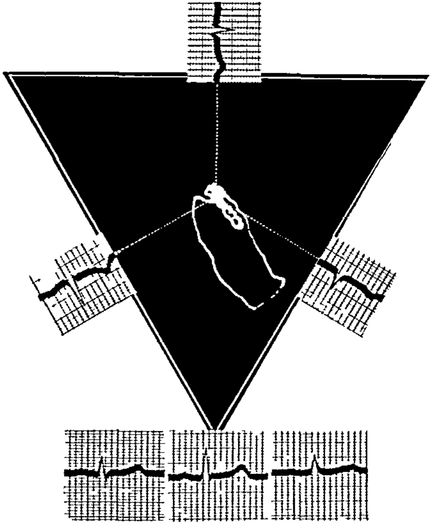


FIGURE 7 Vectorcardiogram of a normal subject taken by the method described in the text. The large loop corresponds to the Q R S group the small inside loop corresponds to the T wave The standard limb leads are reproduced below the triangle and are also shown at the sides of the triangle in their proper orientation

If the standard three lead electrocardiogram is greatly enlarged, the areas subtended by the various deflections may be measured by means of an accurate planimeter and may then be expressed in standard units (microvolt seconds[16]) Einthoven s law and the principles of Einthoven s triangle apply to areas inscribed during a given interval in the same

way that they apply to deflection amplitudes at a given instant, the area of a deflection is merely its average amplitude multiplied by its duration. Consequently the area of any deflection or group of deflections in Lead II must be equal to the sum of the areas of the deflections in Leads I and III written during the same interval. If areas are substituted for deflection amplitudes in the determination of Einthoven's vector, this vector will represent the mean electrical axis during the chosen interval.

The instantaneous electrical axis at a given instant in the Q R S period gives the general direction in which the cardiac impulse passed over

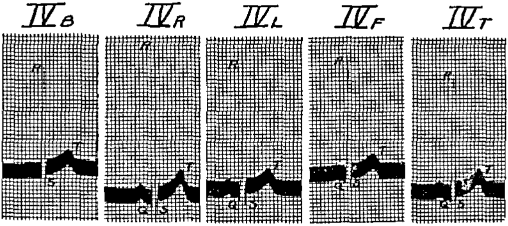


FIGURE 8. Five precordial leads obtained by pairing an electrode placed at the outer border of the cardiac apex of a normal subject with an electrode on the back (IV_B), the right arm (IV_R), the left arm (IV_L), and the left leg (IV_F), and with a central terminal (IV_T) of the kind described in the text.

those portions of the ventricular muscle which were at that moment undergoing activation. The mean electrical axis of Q R S, based on the areas of all the deflections inscribed during the Q R S period, on the other hand gives the average direction in which the cardiac impulse passed over the ventricular muscle as a whole.[16] If the development and decline of the excitatory process were the same in all parts of the ventricular muscle, so that the duration of systole were everywhere uniform, the different parts of the ventricular muscle would pass through the activation and the deactivation process in the same order, and the area of Q R S and the area of T in the same lead must be equal in magnitude but opposite in sign. The sum of these areas, the area of Q R S T, would then be zero in all leads. The area of Q R S T in a given lead may therefore be considered a measure of the mean potential difference produced in that lead by variations in the length of systole in the differ

ent units of ventricular muscle variations brought about by local causes The area of Q R-S T in a given lead is equal to the area of the T deflection which would have been inscribed in that lead if all the ventricular muscle had passed into the active state at the same instant or if the area of Q R S were zero The mean electrical axis of T gives the direction and magnitude of the electrical forces produced by ventricular deactivation and the mean electrical axis of Q R S T the magnitude and direction of the electrical forces produced by local variations in the excitatory process The mean electrical axis of Q R S T may be referred to as the *ventricular gradient*

VII PRECORDIAL AND ESOPHAGEAL LEADS

During the past few years electrocardiographic leads in which a small exploring electrode placed upon the precordium[17] is paired with an electrode placed upon the back or upon one of the extremities have come into widespread use Leads of this kind are very different from the standard extremity leads Because the exploring electrode is very close to the heart in comparison with its fellow the potential variations of the two electrodes differ so greatly in magnitude that an essentially unipolar curve representing the potential variations of the exploring electrode with reference to an indifferent point is obtained The relatively small potential variations of the distant electrode may be further reduced if not eliminated by substituting for this electrode a central terminal connected to the three extremity electrodes employed in taking standard electrocardiograms through noninductive resistors of 5000 ohms each[17]

Precordial leads of the kind in question are in effect semidirect leads from the anterior ventricular surface It has been shown that the ventricular deflections in such leads are similar in general outline to those that might be obtained by placing the exploring electrode in contact with the underlying portion of the ventricular surface

Within the last year a committee appointed by the American Heart Association has established standard methods for the taking of precordial leads[18] When a single precordial lead is taken the precordial electrode should be placed at the outer border of the cardiac apex This electrode may be paired with an electrode on the right arm (Lead IV_R) with an electrode on the left arm (Lead IV_L) with an electrode on the left leg (Lead IV_F) with an electrode on the left interscapular

region (Lead IV_B), or with a central terminal connected through equal resistances of 5000 or more ohms to electrodes on each of the three *extremities mentioned* (Lead IV_T). For all ordinary purposes Lead IV_T or Lead IV_F should be used and the latter should be given the preference until it has been established that the former yields results of equal value. It may be noted that there are certain relations between these leads and the standard limb leads. These relations may be expressed by the following equations:

$$\text{Lead } IV_R = \text{Lead } IV_F + \text{Lead II}$$
$$\text{Lead } IV_L = \text{Lead } IV_F + \text{Lead III}$$
$$\text{Lead } IV_T = \text{Lead } IV_F + \tfrac{1}{3}\,(\text{Lead II} + \text{Lead III})$$

These equations are analagous to Einthoven's equation which states that Lead II = Lead I + Lead III.

When multiple precordial leads are employed the precordial electrode should be paired with an electrode on the left leg or with a central terminal of the kind previously mentioned. In the first case the letters CF followed by a subscript, and in the second case the letter V followed by a subscript should be employed to designate such leads. The subscript used should indicate the position of the precordial electrode according to the following plan: subscript 1 when this electrode is at the right margin of the sternum, subscript 2 when it is at the left margin of the sternum, subscript 3 when it is midway between the left sternal margin and the left mid clavicular line, subscript 4 when it is in the left mid clavicular line, subscript 5 when it is in the left anterior axillary line and subscript 6 when it is in the left mid axillary line. When these letters and subscripts are employed it is understood that in the case of the sternal leads the precordial electrode has been placed at the level of the fourth intercostal space and that in the case of the other leads it has been placed on a line drawn from the left sternal margin in the fourth intercostal space to the outer border of the apex beat and continued around the left side of the chest at the level of the apex.

In taking all precordial leads the galvanometer connections should be made in such a way that relative positivity of the precordial electrode is represented in the finished record by a deflection which lies above the isopotential level. In the past, many observers have made these connections in the opposite way, but it is hoped that this practice will now be abandoned.

It has been recommended further (1) that the greatest diameter of the precordial electrode be 3 cm. or less, (2) that the deflections of precordial leads be designated P, Q, R, S and T and that in the application of these symbols the same conventions be employed as in the case of the standard limb leads; and (3) that in taking precordial leads the electrocardiagraph be so adjusted that a deflection of one centimeter in the finished record corresponds to a potential difference of one millivolt

The precordial electrocardiograms of a normal subject taken and labelled according to these recommendations are reproduced in Figs

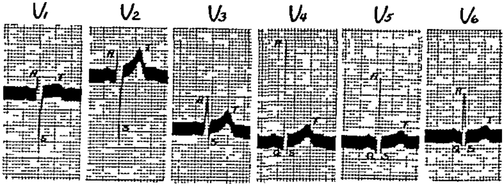


FIGURE 9 Multiple precordial leads taken according to the standard method. These electrocardiograms and those shown in Fig 8 were obtained from the same normal subject.

8, 9 and 10 The first of these figures shows the curves obtained by pairing an electrode at the cardiac apex with an electrode on the back, the right arm, the left arm, or the left leg, or with a central terminal connected through resistances to each of the three extremities mentioned. Fig 9 shows the curves obtained by multiple precordial leads of the kind in which the precordial electrode is paired with a central terminal. Fig. 10 shows the same multiple precordial leads taken simultaneously with Lead I This figure gives the time of the intrinsic deflection of each precordial lead with reference to the first Q R-S deflection of Lead I It will be seen that the intrinsic deflection (chief downstroke of Q R S) is later in the leads from the left side of the precordium than in the leads from the right side.

For the purpose of studying the time intervals of the electrocardiogram, precordial leads have no advantages over standard electrocardiograms Their value lies in the information that may be gleaned from the form of the ventricular complex. In the absence of myocardial infarction of

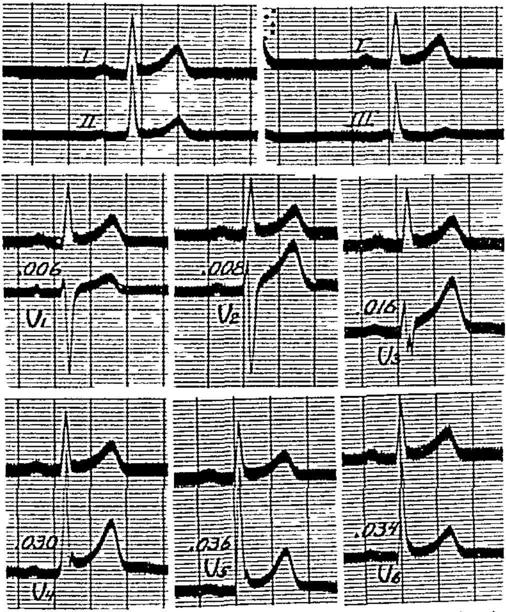


Figure 10. The six precordial leads of Fig. 9 are here taken simultaneously with standard Lead I. The time of the intrinsic deflection (chief downstroke of Q R S) with reference to the first Q-R-S deflection of Lead I is expressed in seconds.

the anterior ventricular wall the Q R S complex usually displays an abrupt downward movement which corresponds to the intrinsic deflection of direct leads and signals the arrival of the cardiac impulse at the epicardial surface of that portion of the anterior ventricular wall which lies beneath the exploring electrode This plus minus or intrinsic shift is preceded by an upward deflection of variable size due to electrical forces produced by the outward spread of the excitatory process through the underlying portion of the ventricular wall This preintrinsic upward deflection may or may not be preceded by an initial downward deflection The intrinsic shift usually carries the trace across the isoelectric level and thus produces a postintrinsic downward deflection but this last deflection may be absent

When the different deflections are designated by letters the initial downward deflection is called Q and the preintrinsic upward deflection R When the intrinsic shift carries the trace across the base line the postintrinsic downward deflection thus produced is called S In the case of normal subjects leads from the right side of the precordium (Leads V_1 and V_2) show a relatively small preintrinsic upward deflection (R) and an early intrinsic shift which crosses the base line and produces a large postintrinsic downward deflection (S) (Fig 10) Leads from the left side of the precordium (Leads V_4 and V_5) display a large preintrinsic upward deflection (R) often preceded by a small initial downward deflection (Q) The intrinsic shift occurs relatively late in the Q R S interval and the postintrinsic downward deflection (S) is usually small and may be absent In all leads in which the exploring electrode is at the left sternal margin or farther to the left T is normally an upward deflection in curves from adult subjects In children it is apparently sometimes a downward deflection The ventricular deflections of precordial leads are on the average about twice as large as those of the standard limb leads

In *esophageal leads* (Lieberson and Liberson[19] and Brown[20]) a small flexible electrode enclosed in a rubber tube which insulates it except at the tip is introduced into the esophagus This electrode is paired with an indifferent electrode or terminal as in the case of precordial leads If the tip of the esophageal electrode is placed in that part of the esophagus which is in close proximity to the wall of the *left auricle* very large auricular deflections showing an abrupt downward shift which corresponds to the intrinsic deflection of direct leads from the auricular

muscle are obtained (Fig. 11). The onset of this shift signals the arrival of the cardiac impulse in that part of the auricular wall which lies nearest the esophageal electrode. Esophageal leads promise to be very helpful in those instances in which the standard leads do not give adequate information regarding auricular activity. They also promise to be useful in a study of the ventricular complex. As yet, they have not been widely used

VIII. DEXTROCARDIOGRAM AND LEVOCARDIOGRAM

The form of the ventricular complex is *determined by the course* of the excitation wave over the ventricular muscle In the normal heart

FIGURE 11. Lead 1 (above) and an esophageal lead (below) in a case of partial heart block. In the esophageal lead the auricular deflections (P) are very large and display a conspicuous intrinsic deflection represented by a sharp downstroke The esophageal electrode was attached to the left hand lead wire, the right hand lead wire was attached to an indifferent central terminal (see text) The esophageal electrode was 40 cm from the teeth. The esophageal lead was taken with the galvanometer at one half the normal sensitivity (N/2) (Cyclopedia of Medicine, F A Davis Co)

the stimulus descends from auricles to ventricles by way of the His bundle and its two branches, right and left. Each ventricle is furnished with its own distributing system, a subendocardial Purkinje plexus formed by the terminal subdivisions of the homolateral bundle branch. Lewis and Rothschild[2] showed that the excitatory process spreads through this Purkinje network with a speed approximately ten times as great as that with which it is transmitted by ordinary ventricular muscle, and that, consequently, the ventricular walls are activated from within outward in a direction nearly perpendicular to the endocardial surface

They demonstrated also that when one branch of the His bundle is cut, the course of the stimulus over the contralateral ventricle is in no way altered, but is normal in every respect. In order to reach the distributing system of the homolateral ventricle, however, the stimulus must traverse the ordinary muscle of the ventricular septum. The activation of this chamber is, therefore, greatly delayed; it does not begin until the activation of the opposite ventricle is nearly complete, and, in addi-

tion it is abnormal with respect to the order in which the various muscle units pass into the excited state

In view of these facts it is clear that the deflections which are written during the first part of the Q R S interval in bundle branch block must be attributed to the normal activation of the contralateral ventricle In right branch block these deflections represent the early phases of the normal left ventricular electrocardiogram and have been referred to by Lewis as the levocardiogram The corresponding deflections of left branch block were referred to as the dextrocardiogram Lewis[21] demonstrated that the initial deflections of the normal ventricular complex are produced by the algebraic summation of these two curves in their proper time relations Wilson and Herrmann[22] confirmed this conclusion regarding the duality of the ventricular complex They found that in the dog the complexes obtained by stimulation of the right ventricle at a point overlying the base of the anterior papillary muscle where the right branch of the His bundle gives off its larger subdivisions were often practically indistinguishable from the complexes produced in the same animal by left branch block Algebraic summation of this extrasystolic dextrocardiogram and the natural levocardiogram gave a curve which closely resembled the initial deflections of the normal ventricular complex In animals in which the right branch of the His bundle had been cut stimulation of the right ventricle within the region mentioned at such a time that the artificial stimulus reached the right Purkinje plexus at the same instant that the natural impulse descending from the auricles reached the left yielded ventricular complexes which differed in no respect from the normal complexes of the same animal

IX BUNDLE BRANCH BLOCK

The last few years have witnessed a complete reversal of opinion with respect to the interpretation of the two chief types of electrocardiograms encountered in human bundle branch block [22, 23, 24] Curves of the more common type in which the chief deflection of the Q R S group is upward in Lead I and downward in Lead III were formerly held to represent right but are now attributed to left branch block Curves of the less common kind in which the chief deflection of the Q R S group is downward in Lead I and upward in Lead III are now ascribed to right instead of to left branch block The observations which have led to this revolution have been of several kinds (1) Stimulation of the an

terior surface of the human right ventricle exposed for the purpose of draining the pericardium, yields curves in which the chief Q R S deflection in Lead I is invariably upward, while stimulation of the anterior surface of the left ventricle yields curves in which the chief Q R S deflection of Lead I is invariably downward [24] (2) Section of the left branch of the His bundle of the human heart revived after death by perfusion of the heart and lungs *in situ* yields branch block curves of the more common type, section of the right branch yields branch block curves

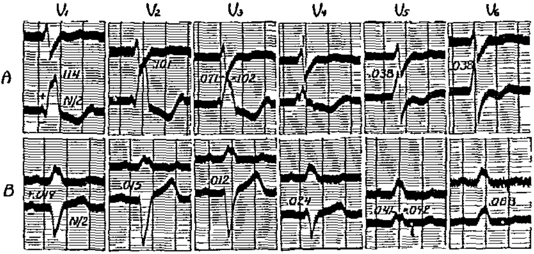


FIGURE 12 *A* Serial precordial leads taken simultaneously with Lead I (above) in a case of right bundle branch block The decimal figures give the time of the chief downstroke (intrinsic deflection) with reference to the onset of the earliest ventricular deflection in Lead I Where two conspicuous downstrokes are present the time of each is indicated The surface of the right ventricle was activated about 0 06 second later than the surface of the left *B* Serial precordial leads in a case of left bundle branch block The surface of the right ventricle was activated about 0 07 second earlier than the surface of the left The time intervals are fifths of a second In the case of the precordial leads the ordinate scale is 2 mv per cm (N/2) The precordial electrode was attached to the left hand lead wire and paired with a central terminal (Cyclopedia of Medicine F A Davis Co)

of the less common type [25] (3) Experiments on the monkey, carried out in the Dutch East Indies, have shown that in this animal section of the left branch of the His bundle yields curves similar to those which characterize the commoner type of human branch block section of the right branch yields curves of the opposite type [26] (4) In human branch block of the common type, the interval between the first ventricular deflection of the electrocardiogram and the onset of the carotid pulse is on the average, greater than in normal subjects, indicating that systole of the left ventricle is abnormally delayed [27] (5) In bundle

branch block of the common type, precordial leads (Fig. 12 *B*) from the left side of the precordium display an abnormally late, leads from the right side an early, intrinsic deflection, indicating that there is an abnormal delay in the arrival of the excitation process at the epicardial surface of the left ventricle, whereas the surface of the right ventricle receives the cardiac impulse at the normal time.[28] In bundle branch block of the less common variety, precordial leads (Fig. 12 *A*) indicate that activation of the right ventricle is abnormally delayed, whereas activation of the left ventricle takes place at the normal time.

In human bundle branch block the lesion responsible for the interruption of conduction through the main stem of the branch involved is seldom the sole cardiac abnormality present. It is often accompanied by lesions affecting the conductivity of other parts of the intraventricular conducting system. In the majority of cases there is present, in addition, enlargement of the right or left ventricle or of both, some peculiarity in the position of the heart, as a consequence of enlargement, myocardial infarction, or some other myocardial disturbance. Since any of these factors may have a profound effect upon the form of the ventricular complex, it is not surprising that the configuration of the electrocardiographic deflections in bundle branch block is highly variable.

In the past it has been the general custom to restrict the diagnosis of bundle branch block to those cases of intraventricular block in which the ventricular complex has the following characteristics: (1) A Q R-S interval measuring between 0.12 and 0.20 second, and extending over one-third or more of the period occupied by the ventricular complex as a whole, (2) conspicuously notched or slurred Q-R S deflections of large amplitude in Leads I and III; (3) large T deflections opposite in direction to the chief Q R S deflection in Leads I and III; (4) Q-R S deflections of the discordant type, in which the chief initial deflection of Lead I is opposite in direction to the chief initial deflection of Lead III. While many human branch block curves display all these characteristics, an equal or greater number do not. In the writer's opinion, the vast majority of all electrocardiograms in which the Q-R-S interval measures 0.12 second or more and in which conspicuous notching or slurring of the Q-R-S deflections is present should be ascribed to conduction defects involving the main stem of the right or the left bundle branch. In cases of this kind studied in the writer's laboratory in which there was a con-

spicuous S deflection in Lead I (Fig 13), it has been possible with very rare exceptions to demonstrate by means of precordial leads an abnormal delay in the activation of the right ventricular surface, in cases in which there was no conspicuous S deflection in Lead I (Fig 14), it could almost always be demonstrated in the same way that there was an abnormal delay in the activation of the left ventricular surface Curves of the former type should therefore be classified as right bundle branch block, and curves of the latter type as left bundle branch block The

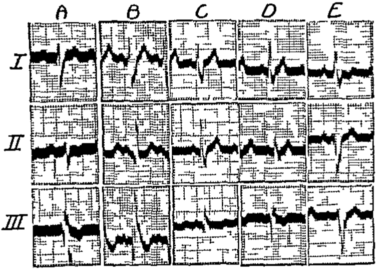


FIGURE 13 Right bundle branch block A series of electrocardiograms which display a Q R S interval measuring 0 12 second or more and a conspicuous S deflection in Lead I In each case serial precordial electrocardiograms showed abnormally late activation of the surface of the right ventricle (Cyclopedia of Medicine F A Davis Co)

direction and size of the T deflections the size of the Q R S deflections and direction of the Q R-S deflections in Leads II and III are immaterial

In experiments upon animals, section of the one or the other bundle branch yields the early phases of the dextrocardiogram or of the levocardiogram, as the case may be, and it is a simple matter to determine whether the individual deflections of the normal Q R S group in a given lead should be ascribed solely or chiefly to right or to left ventricular events

Since the form of the ventricular complex in human bundle branch block, both right and left, is extremely variable, and since the conduction defect is seldom the only cardiac abnormality present, there is as yet no certainty as to the form of the normal human dextrocardiogram

and the form of the normal human levocardiogram, or as to whether the normal Q, R, or S deflection of a given lead is derived solely or chiefly from the former or from the latter. Cases in which the disappearance of the conduction defect is followed by the return of ventricular complexes of normal outline are of great interest in this connection, but such cases are uncommon.

X. PREPONDERANCE

When Einthoven began to apply the string galvanometer to the study of heart disease, he observed that certain valve lesions, when accompanied by great cardiac enlargement, yielded electrocardiograms of distinctive type In cases of mitral disease in which preponderant hypertrophy of the right ventricle was believed to be present, the chief initial deflection of the ventricular complex was downward in Lead I and upward in Lead III. In aortic disease and in other conditions in which preponderant hypertrophy of the left ventricle was suspected, curves of the opposite type were recorded.

These observations have been abundantly confirmed. The electrocardiographic signs of right axis deviation (right ventricular preponderance) and of left axis deviation (left ventricular preponderance) may be summarized as follows:

Right axis deviation	Left axis deviation.
Q is largest in Lead III.	Q is largest in Lead I.
R is largest in Lead III	R is largest in Lead I.
S is largest in Lead I and is abnormally large in this lead.	S is largest in Lead III and is abnormally large in this lead.
The index $(R_1—S_1)—(R_3—S_3)$ is negative and outside normal limits.	The index is positive and outside normal limits.
The mean electrical axis of Q R S is shifted in the clockwise direction and lies beyond the vertical. ($\alpha = +90°$.)	The mean electrical axis is shifted in the counterclockwise direction and lies beyond the horizontal. ($\alpha=0°$)

Right axis deviation is most commonly seen in the newborn, in mitral stenosis, and in congenital pulmonary stenosis; left axis deviation, in aortic disease, in arterial hypertension with or without nephritis, and in arteriosclerotic heart disease.

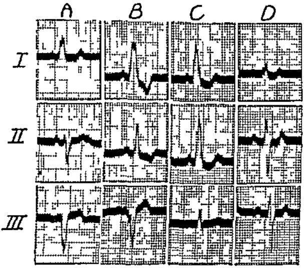


FIGURE 14 Left bundle branch block A series of electrocardiograms which display a Q R S interval measuring 0 12 second or more but no conspicuous S deflection in Lead I In each case precordial electrocardiograms showed abnormally late activation of the surface of the left ventricle. (Cyclopedia of Medicine F A Davis Co)

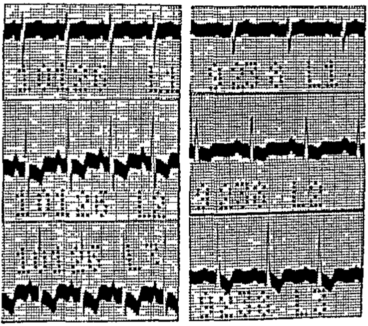


FIGURE 15 Two electrocardiograms from patients with high grade mitral stenosis Both show conspicuous right axis deviation (Cyclopedia of Medicine F A Davis Co)

tricle during this period as compared with later life He attributed the occurrence of signs of slight right or slight left preponderance in normal individuals to unusual variations in the relative weight of the two ventricles, which in his control subjects who had died of cancer, varied within wide limits In a small series of cases, in which the heart was greatly hypertrophied and in which he was able to make a direct com

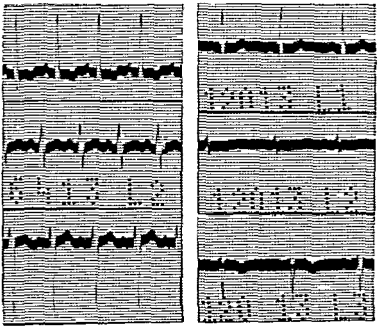


FIGURE 16 Two examples of left ventricular preponderance. No. 6413 is the electrocardiogram of a patient with luetic aortic insufficiency No 12013 is the electrocardiogram of a patient with arteriosclerotic heart disease and cardiac failure. (Cyclopedia of Medicine F A. Davis Co.)

parison between the form of the electrocardiogram and the ratio of the weight of the left ventricle to the weight of the right, a close agreement was found

In a subsequent study by Herrmann and Wilson[31] in which a similar comparison was carried out in a larger series of cases it was found that although the agreement was good in instances in which the heart was greatly hypertrophied, striking discrepancies were sometimes encountered when it was normal in size or only very slightly enlarged

In attempting to account for these discrepancies, the authors called attention to several factors which might modify or nullify the influence exerted by the relative weight of the two ventricles upon the form of the ventricular complex In a previous article they had shown that incom

plete branch block produces complexes transitional in form between those characteristic of complete branch block and complexes of normal outline, and that such curves are not easily distinguished from the curves ascribed to ventricular hypertrophy They pointed out that peculiarities of the *ventricular conducting tracts might have a similar effect* by determining the order in which the two ventricles passed into the active state Others had already shown that counterclockwise rotation of the heart about a dorsoventral axis *might modify the normal ventricular* complex in the same direction as left clockwise rotation, in the same direction as right ventricular hypertrophy It is, of course, obvious that rotation of the heart could not modify the initial deflections alone, it must alter the auricular complex and the T deflection as well To explain completely the more pronounced grades of electrocardiographic preponderance on this basis would require an amount of rotation that is physically impossible

It has frequently been suggested that the changes in the form of the electrocardiogram seen in axis deviation are due to rotation of the heart about its long axis induced by asymmetric enlargement of the two ventricles Rothberger and Winterberg[12] have shown that in dogs curves similar to those characteristic of left axis deviation may be produced by *section of the anterior subdivision curves of the opposite type, by section* of the posterior subdivision of the left bundle branch

Many different views have been expressed as to the cause of the *association of right axis deviation with preponderant hypertrophy or* enlargement of the right ventricle, and of left axis deviation with preponderant hypertrophy or enlargement of the left ventricle At a time when it was thought that branch block curves of the common type represented right bundle branch block, the general resemblance between the early phases of these curves and those of left axis deviation led to the belief that the configuration of the latter was due to the dominance in the bicardiogram of an abnormally large levocardiogram generated by the enlarged left ventricle For similar reasons it was believed that in right axis deviation the dextrocardiogram was predominant It would seem that the demonstration that left is *the* common and right *the rare* type of bundle branch block must lead to the conclusion that the dextrocardiogram dominates the Q R S group in left axis deviation, and that *the levocardiogram dominates it in right axis deviation* This would

ponderant hypertrophy of the right ventricle increases the number of muscle units activated in a left to right and downward direction. Since the position of the mean electrical axis of Q-R-S is determined by the direction in which the average unit of ventricular muscle is activated, it is, therefore, obvious that it should theoretically point upward and to the left in preponderant hypertrophy of the left ventricle and in left bundle branch block, and in the opposite direction in preponderant hypertrophy of the right ventricle and in right bundle branch block.

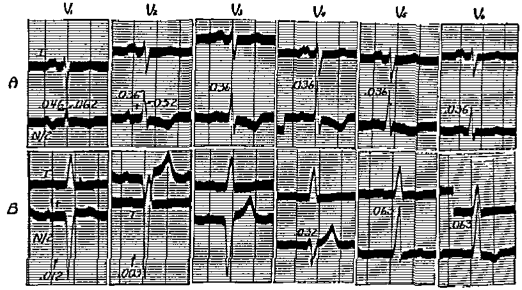


FIGURE 17 *A*, Serial precordial leads in a case of preponderant hypertrophy and enlargement of the right ventricle (mitral stenosis) The intrinsic deflection is later in the leads from the right side of the precordium (V_1 and V_2) than in the leads from the left side *B*, Serial precordial leads in a case of preponderant hypertrophy and enlargement of the left ventricle (syphilitic aortic regurgitation) The intrinsic deflection is abnormally late in the leads from the left side of the precordium (V_5 and V_6). The ordinate scale for these leads is 2 mv per cm (N/2) The clinical diagnosis and the type of preponderant hypertrophy specified was confirmed at necropsy in each instance. (Cyclopedia of Medicine, F A Davis Co)

The chief differences consist in an exaggeration of the size of the postintrinsic downward deflection (S) in leads from the right side of the precordium, of the size of the preintrinsic upward deflection (R) and sometimes of the initial downward deflection (Q) in leads from the left side of the precordium, and of the interval which normally separates the onset of the intrinsic deflection in the former curves and its onset in the latter The indications of preponderant hypertrophy of the one or the other ventricle may be present in precordial leads and absent in the standard leads or *vice versa*.

XI. ABNORMALLY LARGE OR SMALL Q-R-S DEFLECTIONS; NOTCHING OF Q-R-S

Very large Q R-S deflections, measuring well over two millivolts (2 cm.) are most commonly seen in the electrocardiograms of young individuals with very large hearts and good or fairly good cardiac function, particularly in cases of congenital heart disease and of rheumatic aortic insufficiency. In hypertension associated with great cardiac enlargement they are encountered less frequently. The Q-R S deflections of the standard leads are considered abnormally small when the largest deflection in any lead measures less than 0 5 millivolt (5 mm.). Small deflections of normal outline may occur in normal subjects and too much *stress should not be placed upon such deflections when there is no other* abnormality of the ventricular complex. Very small deflections of bizarre outline are commonly seen in patients with high grade cardiac failure associated with edema. The deflections sometimes, although not always, get larger as the cardiac function improves and the edema disappears. Small deflections are also frequently encountered in myxedema and in myocardial infarction, less often in a variety of other conditions

Marked splintering or notching of Q-R S in Lead III when the deflections in this lead are small is in no way abnormal A similar splintering or notching of Q-R S does not occur normally in Lead I nor in Lead II Slight notching or slurring of Q R-S in these leads is, however, common enough. In normal precordial electrocardiograms notching is not rare and appears to be due to the time interval which separates activation of the surface of the thin right ventricular wall and activation of the surface of the thick left ventricular wall. Deep notching of the chief Q R-S deflection near its apex in leads of large amplitude suggests the presence

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of intraventricular block It is frequently associated with a slight increase in the Q R S interval Initial deflections which resemble the letter M or the letter W in outline and are of small size have no significance when present in Lead III only when present in Lead I or Lead II they suggest intraventricular block or myocardial infarction In general however, *great caution should be exercised in the interpretation of notching, slurring or other minor abnormalities of the Q R S deflections*

XII T DEFLECTION

Investigations dealing with abnormal T deflections have for the most part been concerned with the importance of inversion of this wave in one or more leads Inversion of T in Lead III alone is frequent in normal subjects inversion of T in Leads I and III without inversion in Lead II is impossible The pathologic combinations therefore are inversion in Lead I alone in Leads I and II, in all three leads or in Leads II and III It is not clear at the present time that the leads involved is a matter of much practical importance, or what the precise significance of the different combinations may be

One difficulty in the solution of problems involving the significance of abnormal T deflections arises from the circumstance that the form of T is to a considerable extent dependent upon the contour of the initial ventricular deflections It is determined by the order in which the ventricular muscle passes out of the excited state and this in turn depends upon at least two independent factors (1) Upon the order of activation which controls the form of the Q R S deflections and (2) upon the presence of variations normal or abnormal in the duration of systole in different muscle units Such variations are due to local causes It is desirable to be able to distinguish between secondary abnormalities of T due to the first factor and primary abnormalities due to the second Abnormalities of the first kind have no significance other than that which may be ascribed to the abnormalities of the Q R S deflections upon which they directly depend

It has been pointed out on a previous page that the area of Q R S T in a given lead is equal to the area of the T deflection which would have been inscribed if the area of Q R S were zero By measuring the area of Q R S T it may therefore be determined whether the form of Q R S is solely responsible for inversion of T in a given instance or whether

the latter is dependent upon abnormal local variations in the excitatory process The diphasic character of the ventricular complexes commonly seen in bundle branch block and in many cases of axis deviation is directly due to the large area of Q R S which controls the direction of the T deflection Ventricular complexes of the normal type are polyphasic because the area of Q R S is too small to overbalance the effects produced by local variations in the excitatory process When these local variations are very

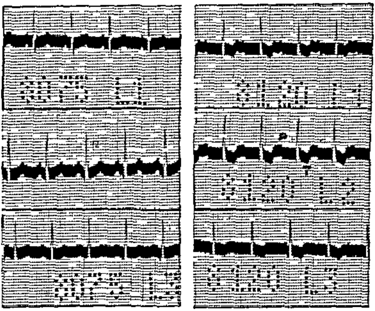

FIGURE 18 Two electrocardiograms from the same patient. No 8075 was taken before and No 8120 after digitalization The latter shows the inverted T deflections and the prolonged P R interval commonly produced by full doses of digitalis (Cyclopedia of Medicine F A. Davis Co)

great they may determine the direction of T *even though* Q R S has a large area

If the electrocardiogram is greatly enlarged the area of Q R S T may be accurately measured with a planimeter, but this is a laborious process not adapted to the interpretation of clinical electrocardiograms In many instances however the area of Q R S T may be estimated by *inspection with sufficient* accuracy to determine whether inversion of T is secondary or primary Since secondary inversion of T has no independent significance, attention may be confined here to primary inversion due to abnormal local variations in the excitatory process The conditions in which inverted T waves of this kind may occur are exceedingly numerous

First of all may be mentioned the changes in T produced by digitalis As was shown by Cohn Fraser and Jamieson when given in adequate doses this drug produces a gradual depression of that portion of the ventricular complex which immediately succeeds the last initial deflection the ascending limb of T and then its later portions are successively involved so that it is finally replaced by a U shaped depression (Fig 18) The end of T is ordinarily the last part to become negative The effect is usually similar in all leads and occurs in normal subjects and in all types of heart disease T waves which are inverted before digitalis is given become deeper The amount of digitalis required to produce these changes is somewhat variable

Changes in the form of the T deflection may occur after the administration of quinidine or of insulin after drinking large quantities of iced fluid after the inhalation of cigarette smoke (White[33]) and in alkalosis or acidosis

Inverted T waves may occur as a transient phenomenon in all types of acute heart disease acute rheumatic pericarditis and myocarditis diphtheritic myocarditis the acute myocarditis of trichinosis toxic goiter myxedema during anesthesia during an attack of angina pectoris and in infections and intoxications of various kinds

As a permanent phenomenon inversion of T may be seen in all types of chronic heart disease Although not always present in angina pectoris it may be the only positive sign of cardiac disease that can be elicited in this condition and therefore is of great value in diagnosis

In adults the T deflection of precordial leads is normally an upward deflection in those leads in which the precordial electrode is placed to the left of the sternum In leads in which the exploring electrode is placed to the right of the sternum and in children it may be a downward deflection Abnormal T waves may occur in precordial leads when they are absent in the standard leads

XIII CORONARY OCCLUSION

In the diagnosis of recent myocardial infarction the electrocardiogram is of the greatest importance[34] It frequently yields data which point unequivocally to the presence of infarction when physical and x ray examinations disclose no definite cardiac abnormality *Because the changes in the electrocardiogram are progressive and the sequence of*

changes is characteristic, it is important to obtain a series of curves whenever it is possible.

The earliest change consists in a temporary displacement of the R S T junction and the portion of the ventricular complex which immediately follows it (R-S-T segment). Slight permanent displacement (1 mm.) of this junction and segment is sometimes seen in normal subjects, and more pronounced permanent displacement is common in bundle branch block and in axis deviation.

Apart from the displacement of the R-S T segment without much change in the position of the R-S T junction commonly seen after the administration of digitalis, temporary R S-T displacement is almost always due either to very recent coronary occlusion or to acute pericarditis. In the former, the displacement in Lead I is usually opposite in direction to the displacement in Lead III, while in the latter the direction of the displacement is usually the same in all three leads

The R-S-T displacement of coronary occlusion rapidly diminishes in most cases and seldom lasts more than a few hours or a few days As it declines, characteristic T wave changes almost invariably develop The decline of upward R-S-T displacement is accompanied by sharp inversion of the end of the T wave; as the inversion becomes more pronounced, it progresses backwards towards the Q R-S group. The final result is a very large, sharply inverted, V-shaped T deflection with a shoulder on its descending limb, which is convex towards the base line. These peculiar T waves have been referred to as "cove plane T waves" and as "coronary T waves." Their appearance is most distinctive during the period when some displacement of the R-S-T junction is still present. Downward R-S-T displacement is followed by T wave changes of the same kind, except that the direction of T is reversed so that it becomes a sharp-peaked, upward deflection. The T wave changes ordinarily reach their maximal development in two or three weeks, and persist for several months. In the course of time, inverted "coronary T waves" are replaced by upright T waves, or gradually lose their distinctive outline.

The kind of changes which develop in the different standard leads depends upon the location of the infarcted region. When the infarct lies on the anterior wall and involves the left margin of the heart upward R-S-T displacement and inversion of T occur in Lead I and changes of the opposite type in Lead III. These changes in the final deflections of

the ventricular complex are very often accompanied by alterations in the QRS deflections (Fig. 19). In Lead I these deflections become small and the most characteristic configuration is a prominent and sometimes broad Q wave followed by an R wave 5 mm. or less in height. In Lead III Q is not present. R may be the only initial deflection in this lead but very often it is followed by a large S. The ventricular deflections of Lead II usually resemble those of Lead III but may resemble those of Lead I.

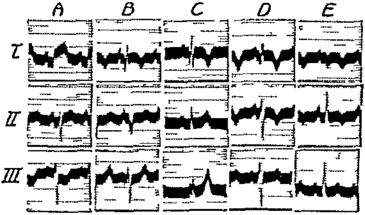

FIGURE 19. Series of electrocardiograms which display changes in the ventricular complex of the kind produced by infarction of the anterior ventricular wall. In Lead I the QRS deflections are small and a conspicuous Q deflection is present. In A there is pronounced displacement of the RST junction and segment. In B, C, D and E sharply inverted "coronary" T waves occur in Lead I or in Leads I and II. (Cyclopedia of Medicine, F. A. Davis Co.)

When the infarct involves the posterior wall and diaphragmatic margin of the heart, prominent Q waves appear in Leads II and III and these are the leads in which upward RST displacement and inversion of T occur (Fig. 20). In Lead I, Q is usually absent or very small, the RST displacement is downward and the altered T waves are upright.

Unlike the changes in the T wave, those which occur in the QRS group are, as a rule, permanent and often make it possible to render a tentative diagnosis of old myocardial infarction in cases in which the coronary accident occurred several years before the electrocardiographic examination. The most characteristic QRS changes in anterior infarction consist in a mean electrical axis which is nearly vertical, a Q wave in Lead I measuring at least 1 mm. and at least one fifth as large as the largest R in any lead, and an R wave in Lead I measuring 5 mm. or less

in height. The most characteristic changes in posterior infarction consist in a Q wave in Lead III at least one half as large as the largest Q R S deflection in any lead, a Q wave in Lead II measuring at least 1 mm and at least one fourth as large as R in Lead II, and a mean electrical axis which is shifted to the left or is in the normal position. Large Q waves in Lead III only are common in patients who give a history which suggests coronary occlusion or who complain of anginal pain, but since they sometimes occur in pregnant women in association with elevation of the diaphragm and in normal subjects who are obese, they are of comparatively little help in diagnosis. A positive diagnosis of coronary

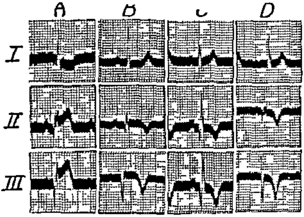

FIGURE 20 Series of electrocardiograms of the kind seen in cases of infarction of the posterior ventricular wall. Conspicuous Q deflections are present in Leads II and III. In *A* there is pronounced displacement of the R S T junction and segment. In *B*, *C* and *D* inverted coronary T waves are present in *Leads II and III*. (Cyclopedia of Medicine, F. A. Davis Co.)

occlusion should not be based upon the electrocardiogram alone unless unequivocal changes of characteristic type are present in both the initial and the final deflections.

When the anterior wall of the heart is infarcted, characteristic changes are present in the precordial electrocardiogram in many instances in which they are absent *in the standard three lead electrocardiogram*. They consist in the sequential development of pronounced upward displacement of the R S T junction and segment, of an abnormally large initial downward deflection (Q) which is often the sole deflection of the Q R S group, and of very large inverted T deflections of the coronary type (Fig. 21). These characteristics are often most conspicuous when the precordial electrode is placed directly over the apex beat (Lead V_4 or

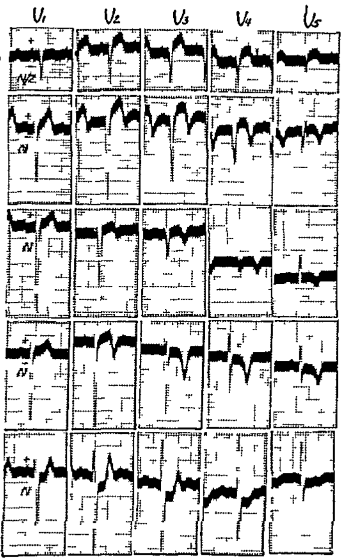

FIGURE 21 Serial precordial electrocardiograms obtained in five cases of coronary occlusion. In A, B, C and D the changes in the ventricular complex point to infarction of the anterior ventricular wall. In the first (A) an abnormally large initial downward deflection is followed by upward displacement of the R S T junction and segment. In B a later stage of infarction is represented: upward displacement of the R S T segment is giving place to sharp inversion of the T deflection. In C and D the "coronary" T waves are well-developed; in the former the Q R S changes are characteristic, in the latter they are absent or questionable. In E there is downward displacement of the R S T junction and segment pointing to very recent infarction of the posterior ventricular wall, but the Q R S deflections are not abnormal. In A the ordinate scale is 2 mv per cm (N/2). In B, C, D and E the ordinate scale is 1 mv per cm (N). (Cyclopedia of Medicine, F. A. Davis Co.)

Lead IV_F), but in some instances they are more pronounced in leads in which this electrode is placed near the left sternal border or halfway between this border and the apex beat (Leads V_2 and V_3). When Q-R-S changes are *present alone, they should not be considered of diagnostic importance unless they occur in leads in which the exploring electrode is placed to the left of a point midway between the left sternal margin and the mid clavicular line.*

When the posterior wall of the heart is infarcted, precordial leads are rarely helpful except during the period when R-S-T displacement is present (Fig. 21). During this period they usually show conspicuous *R-S-T displacement in the downward direction.*

In some cases, myocardial infarction leads to temporary or permanent disturbances of intraventricular conduction (intraventricular block, bundle branch block) which tend to obscure the characteristic changes described in preceding paragraphs. *In other cases, the chief features of the ventricular complexes of the standard leads are the small size and bizarre outline of the Q-R-S deflections.* Atrioventricular block, paroxysmal ventricular tachycardia, auricular fibrillation and other disturbances of rhythm frequently occur.

XIV. ANGINA PECTORIS

Anginal pain is frequently associated with electrocardiograms of normal outline; more often intraventricular block, abnormal inversion *of the T deflections, large Q waves in Lead III, or left axis deviation is* present. These changes often offer the only objective evidence of cardiac disease, and they are of diagnostic importance for this reason. They are *not, however, distinctive, since they commonly occur in association with* many different cardiac abnormalities. When an electrocardiogram is taken during an attack of anginal pain, spontaneous or induced, transient displacement of the R-S-T junction and segment or transient inversion *of the T deflection is not infrequently observed. Such changes suggest* temporary myocardial ischemia and are sometimes of value in diagnosis when the chest pain is atypical.

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CHAPTER XXVIII

ELECTROCARDIOGRAPHY

By Samuel Bellet, M D, and Thomas M McMillan, M D

Since the theoretical side of electrocardiography has been discussed in another portion of this book, this chapter will concern itself chiefly with the practical aspects of the subject and the use of this graphic method in clinical practice

I THE ROLE OF THE ELECTROCARDIOGRAM IN CARDIAC DIAGNOSIS

Certain misconceptions are sometimes encountered regarding the function served by the electrocardiograph in the diagnosis of cardiac disease This ranges from the opinion that it is of little value to the belief that the electrocardiograph is the final court for deciding the presence or absence of heart disease Somewhere between these two views lies the truth Undoubtedly this graphic method gives information relative to the heart, which can be obtained by no other means However, the physician who uses the electrocardiograph wisely will remember its limitations and will treat the method as a supplement to and not as a substitute for a careful history, physical examination and roentgen study

There are certain cardiac conditions in which the electrocardiograph is particularly valuable conditions in which the information contributed by the electrocardiogram is on a par with or even more important than that contributed by clinical study Among such conditions are (1) the cardiac arrhythmias (2) pericarditis occasionally (3) bundle branch block and lesser grades of A V heart block, (4) the degree of effect of digitalis on the myocardium, (5) myocardial involvement in certain infectious diseases and abnormal metabolic states and (6) particularly acute coronary occlusion The chance that the graphic method will reveal some evidence of myocardial derangement, not obtainable by other meth

ods of examination is so definite that no study of a heart can be regarded as complete which does not include an electrocardiogram

Among the limitations of the electrocardiographic method perhaps *the chief one is the fact that definite, even serious heart disease may exist in the presence of a normal or a relatively normal electrocardiogram* The use of precordial leads has reduced somewhat the number of such instances Furthermore the degree of electrocardiographic change does not necessarily mirror the degree of myocardial disease We must therefore adopt this point of view when the electrocardiogram reveals unmistakable and characteristic changes these are to be accepted as evidence of a severe cardiac disorder when the alterations are slight or even when the electrocardiogram is normal we are not justified on this evidence alone in concluding that no cardiac disease exists

Another limitation lies in the fact that between the rather wide range of variation observed in normal tracings and those that clearly denote myocardial disease there is an important group where the significance of the alterations is equivocal Certain changes are neither entirely normal nor do they clearly represent disease Examples of such alterations are low T_1 with normal amplitude of Q R S complexes slurring of Q R S complexes inverted T_2 low amplitude of the Q R S complexes without other changes and occasional ectopic beats Such findings should be interpreted conservatively They should not be accepted as evidence of disease unless or until some other confirmatory evidence of disease is obtained

II THE INSTRUMENT AND METHOD

Before considering the features of the electrocardiogram we wish to discuss briefly the apparatus and the technic employed in its use

A muscle when activated to contract produces some electrical activity the magnitude of which depends on the size of the muscle When the body is at perfect rest, the muscle chiefly acting is the heart, the other large masses of muscle being in a relatively inactive state The current developed by the heart muscle is transmitted through the tissues to the peripheral parts of the body where it may be picked up by suitable electrodes and transmitted to the electrocardiograph In the indirect or limb leads the current developed which reaches the instrument measures 1 to 4 mv in Lead II

Two types of machines are employed in taking electrocardiograms, the string galvanometer and the oscillograph models.

The string galvanometer consists of a powerful electromagnet between the poles of which is situated a finely drawn quartz string filmed with silver, 0.002 to 0.005 mm. in diameter. The current produced by the heart and carried to the instrument through suitable electrodes and wires, passes through the string which has a low resistance (1000 to 10,000 ohms) and produces oscillations which are magnified through a system of lenses and projected on moving sensitive paper or film where it is photographed. Time intervals of 1/5 and 1/25 of a second are photographed simultaneously with the oscillation of the string.

In the oscillograph type of electrocardiograph which has been recently introduced, the recording part of the instrument consists of a small mirror attached to a movable coil situated in a magnetic field. The mirror swings with the movements of this coil when a sufficiently large current enters the circuit and the reflection of the beam of light is photographed on moving sensitized photographic film or paper. The sensitivity of this instrument is increased by a three stage vacuum tube amplifier which enables it to record the small currents produced by the heart. Its sensitivity is adjusted so that tracings may be taken without considering the patient's own skin resistance. This is due to the fact that an extremely high resistance is already present in the amplifying circuit compared to which the resistance of the body is small in proportion. In both types of instruments the film or sensitive bromide paper is run at a usual speed of 25 mm. per second.

A. Technic Employed in Taking Electrocardiograms: Electrocardiographic tracings are taken with the patient in either the recumbent or sitting positions.* It is important that he be made as comfortable and as relaxed as possible, avoiding tremors of the arms and legs. The distal portions of the left and right arm and left leg are rubbed with a cloth saturated with salt solution. Recently an electrode paste containing salt and a mild abrasive pumice base has been found more suitable for this purpose. German silver electrodes are firmly applied to these areas which, it is emphasized, must be well prepared.

* Slight changes are occasionally observed in the electrocardiograms taken in these two positions. In comparing electrocardiograms in the same patient, this point should be borne in mind.

B. The Leads: The standard electrocardiogram consists of the three-limb leads. Lead I is secured by recording the electrical activity between the contacts of the right and left arm; Lead II, that between the right arm and left leg and Lead III, that between the left arm and left leg.

In addition to the three indirect or limb leads, precordial leads are now frequently employed. Their value in the diagnosis of coronary occlusion was first established by the work of Wolferth and Wood[2] and later by Wilson[3]. Since that time, they have proved of value in many *other conditions, e. g., acute pericarditis, digitalis effects, bundle branch* block, right and left ventricular hypertrophy, hypertension and angina pectoris.

An electrode 3 cm. in diameter is applied to various regions of the precordium, the most important position being the region of the cardiac apex. This is coupled with an electrode placed on the left leg, angle of the left scapula, right arm or left arm. The electrode placed in the precordial region is the most important; for upon its position chiefly depends the configuration of the resulting (precordial) electrocardiogram.[4] Alteration of even a few inches in the position of this electrode may definitely change the character of the electrocardiogram. The electrode close to *the heart is called the exploring electrode. The electrode placed on the* arm, leg or angle of the left scapula is called the indifferent electrode because change of its position alters the electrocardiogram little or not at all. *Since the situation of the exploring electrode is extremely important for correct electrocardiographic interpretation, its placement should not be left to a technician unless he or she has been thoroughly trained in this work.*

Early in the use of precordial leads, considerable confusion resulted from the fact that various investigators used different positions for the precordial leads and different methods of applying electrodes. This confusion has been largely obviated by the Committee of the American Heart Association and the Cardiac Society of Great Britain and Ireland which have recently recommended a standard method for applying the electrodes and a nomenclature to be used in describing precordial leads:[5]

Some of the important recommendations follow:

A. *Nomenclature:* When a lead from a single point in the precordium is used, the exploring electrode should be placed at the apex

and the following terminology applied, depending upon the location of indifferent electrodes:

IV_B—Apex to angle of left scapula.
IV_R—Apex to right arm.
IV_L—Apex to left arm.
IV_F—Apex to left leg.

When leads from two or more precordial points are employed, it is suggested that the precordial electrode be paired with an electrode on the left leg or right arm. It is suggested further, that the letters CF or CR be used followed by a subscript, to be employed to designate such leads, *e. g.*

CF_I—Right margin of sternum to left leg.
CF_{II}—Left margin of sternum to left leg.
CF_{III}—A point midway between the left margin of the sternum and the left mid clavicular line to left leg.
CF_{IV}—Left mid-clavicular line to left leg.
CF_V—Left anterior axillary line to left leg.
CF_{VI}—Left midaxillary line to left leg.

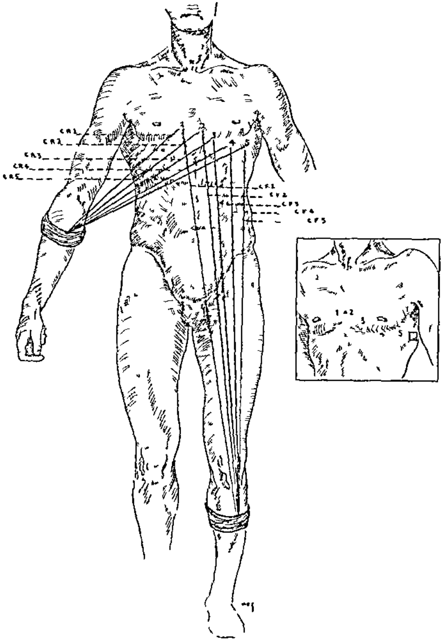
If the right arm instead of the left leg is used for the indifferent electrode, R is substituted for F in the above. Thus we would have CR_I, CR_{II}, etc.

In the sternal leads (CF_I and $_{II}$) the precordial electrode is placed in the fourth interspace. In the case of the other leads (CF_{III}, $_{IV}$, $_V$ and $_{VI}$), it is placed upon a line drawn from the left sternal margin in the fourth intercostal space to the outer border of the apex beat and continued around the left side of the chest at the line of the apex beat or of the junction mentioned.

The galvanometric connections are made in such a way that relative positivity of the precordial electrode is represented in the finished curve by an upward deflection and relative negativity of this electrode by a downward deflection. Thus, to take Lead IV_F, the left leg wire is connected to the precordial electrode and the right arm wire to the left leg electrode; the lead switch is placed on Lead II.

This method makes it possible to assign the letters Q-R-S to the individual deflections of the primary ventricular complex in exactly the same manner as in standard limb leads.

In taking a single precordial lead, Lead IV_F or IV_R should be employed.



Illustrating Method of Application of Electrodes for Chest Leads (See Text)

To take CF leads the left leg electrode is placed in the precordial region in the different positions noted the right arm electrode is placed on the left leg and the electrocardiogram is taken on Lead II To take CR leads the right arm electrode is placed on the right arm the left arm electrode is placed on the precordium in the different positions noted and the electrocardiogram is taken on Lead I (Insert) Patient turned in left oblique position to illustrate application of axillary leads

III THE NORMAL ELECTROCARDIOGRAM IN THE THREE LIMB LEADS

The normal electrocardiogram consists of two portions an auricular complex (P wave) and a ventricular complex (Q R S T portion) The auricular complex or P wave consists of a round blunt or pointed upward deflection *1 to 2 mm in amplitude The P wave represents the spread of* the excitation wave from its origin in the S A node through the auricular muscle It is sometimes followed by a dip called the auricular T wave

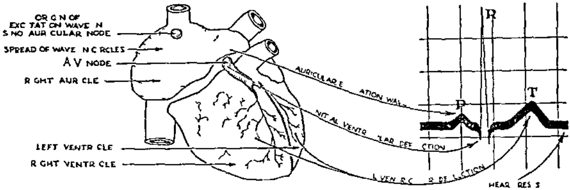


FIGURE 1 Diagram showing relation of electrocardiogram to spread of excitation wave

best seen in tracings of A V heart block Normally the P wave is smooth and upright However there are many exceptions and variations which *will be subsequently discussed*

The P wave is followed by an isoelectric period during which the string remains at rest except in the rare instances in which an auricular T wave is present While the period from the beginning of the P wave to the beginning of the Q R S complex represents the time required for the impulse to spread from the S A node through the auricular muscle and through the A V node and bundle of His to the point of its division into right and left bundle branches in the upper portion of the inter ventricular septum the great majority of this time is occupied by the passage of the impulse through the A V node and bundle of His This interval called the P R interval normally measures from 0 12 to 0 18 second

The Q R S complex is produced by the propagation of the cardiac *impulse through the right and left bundle branches their arborizations* and the Purkinje fibers to the muscle of the ventricles at the termination of the Q R-S complex the entire ventricular muscle has been involved by

the excitation process The duration of the ventricular complex should not exceed 0 1 second

As in the case of the P wave, the normal limits of variation of the Q R S complex are wide For instance, the absence of either the Q wave or the S wave or both waves is not an abnormality In a strictly normal Q R S complex, there is always present an R wave which is more prominent than either the Q or S waves and which moreover is taller in Lead II than in either Leads I or III, it is to be remembered that slight de-

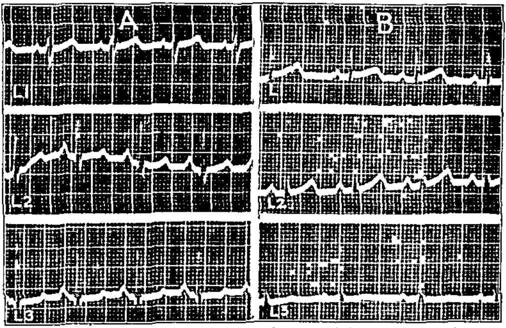


FIGURE 2 Variations in normal electrocardiograms *A* Note the slight right axis deviation This configuration is frequently seen in children and healthy young adults *B* Note the slight elevation of the S T line in Lead I and the shading of the Q R S complex near the base line in Lead II. Both of these changes are seen in individuals with normal hearts

grees of axis deviation frequently develop in normal hearts and do not therefore by themselves constitute evidence of disease So too in a strictly normal Q R S complex the waves are clean cut and unshaded However in certain instances, shading or even notching are seen in apparently perfectly healthy hearts These and other variations will be later discussed

The T wave is the terminal portion of the ventricular complex and represents the retreat of the electrical activity in the ventricle as contrasted to the Q R S complex which represents the stage of invasion It

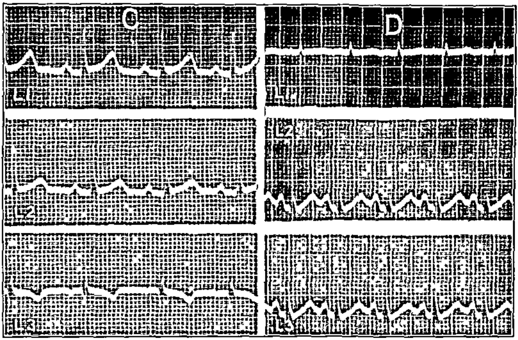


FIGURE 2 *C*, Note the Q waves in Lead III, the inverted T waves in Lead III and the inverted P waves in Lead III When confined to Lead III these changes are of no significance *D*, Note the low amplitude of all waves in Lead I This is of no significance if the amplitude of the waves is normal in the other two indirect leads This configuration has no significance other than to indicate that the electrical axis is approximately 90°

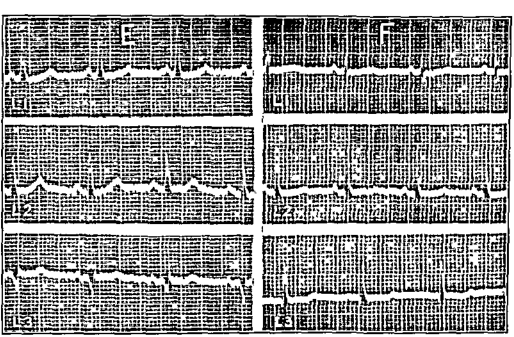


FIGURE 2 *E*, Note the slight left axis deviation and the somewhat notched Q R S complexes in Lead III These changes are seen in entirely normal hearts *F*, Note the low amplitude of the T waves in all three leads This configuration may exist in the presence of a normal heart It is frequently seen in tall individuals whose hearts are long and ptotic.

consists of a blunt, rounded, upward deflection rising gradually from the isoelectric line to a height of 3 to 8 mm and then sloping downward to the base line. The T wave is normally an upright wave. However, since the T wave is so frequently inverted in Lead III, in normal individuals, this cannot be considered as an abnormality.

While one may speak of a normal electrocardiogram and associate that statement with a certain definite configuration of the complexes in the electrocardiogram, *one should remember that like the human face, no two electrocardiograms are identically alike.* It is best, therefore, to think in terms of the "normal range" of the electrocardiogram since there are so many normal variations and deviations. Failure to realize the wide limits of the normal electrocardiogram is one of the chief causes of the misuse of this method In Fig. 2 are illustrated some of the variations shown by normal tracings.

A. Relation of Ventricular Complexes in the Three Indirect Leads: It has been shown by Einthoven,[6] that in the limb leads the waves in Lead II represent an algebraic summation of those in Leads I and III. With upright complexes in all leads, the R waves and T waves are of greatest amplitude in Lead II. In the presence of right and left axis deviation, the amplitude of these complexes varies, depending on their relative positivity or negativity in Leads I and III.

B. The Q-T Interval: The distance between the beginning of the Q wave and the end of the T wave represents electrical systole. It is believed that this interval is the best measurement we have for the duration of mechanical systole.* While the Q-T interval (electrical systole) corresponds fairly closely with the value of mechanical systole as determined by heart sound records, this correspondence does not hold when the Q-T interval is abnormally shortened or lengthened. Mechanical systole is longer in the former and shorter in the latter. The Q-T length is a function of the heart rate, being shorter for faster rates and longer for slower rates. The value for the normal Q-T interval has been established by Bazett[7] where $S^{*} = K\sqrt{c^{\circ}}$, the constant K being 0 37 for men and 0.40 for women. Fridericia's[8] formula is $S = 8\,22\sqrt[3]{c}$ and Hegglin and Holtzman $S = 0.39\sqrt{c}$ for both men and women. The variation in

* s = length of systole
° c = cycle length.

the calculation of systole by these different methods is slight and for practical purposes may be disregarded.

TABLE I

CALCULATION OF ELECTRICAL SYSTOLE BY BAZETT'S FORMULA $S = K\sqrt{c}$

Cycle length in seconds	*Square root of cycle (R-R interval)*	*Duration of Systole*	
		X 0.37 (men)	*X 0.40 (women)*
0.40	0.63	0.233	0.252
0.42	0.65	0.239	0.260
0.44	0.66	0.242	0.264
0.46	0.67	0.250	0.268
0.48	0.69	0.255	0.276
0.50	0.70	0.259	0.280
0.52	0.72	0.266	0.288
0.54	0.73	0.270	0.292
0.56	0.74	0.274	0.296
0.58	0.76	0.282	0.304
0.60	0.77	0.285	0.308
0.64	0.80	0.296	0.320
0.66	0.81	0.299	0.324
0.68	0.82	0.303	0.330
0.70	0.83	0.307	0.332
0.72	0.85	0.315	0.340
0.74	0.86	0.318	0.344
0.76	0.87	0.322	0.348
0.78	0.88	0.326	0.352
0.80	0.89	0.329	0.356
0.82	0.90	0.333	0.360
0.84	0.91	0.337	0.364
0.86	0.92	0.340	0.368
0.88	0.93	0.344	0.372
0.90	0.95	0.348	0.376
0.92	0.96	0.352	0.380
0.94	0.96	0.355	0.384
0.96	0.97	0.359	0.388
0.98	0.98	0.363	0.392
1.00	1.00	0.370	0.400

C. Comparison of Time Relations of the Electrocardiogram With Certain Mechanical Events: (*a*) *The Excitation Process:* The relation of the electrocardiogram to heart sounds is of both theoretical and practical import. The first heart sound begins in man from 0.009 to 0.039 of a second after the beginning of the Q-R-S complex. The relation of the T to the second sound is variable; it may fall 0.03 second before or after the second sound.[9]

The upstroke of P precedes the upstroke of *a* in the human jugular curve by from 0.10 to 0.15 second. The upstroke of R precedes the upstroke of *c* in the human jugular by from 0 10 to 0 15 second.

It therefore appears that the electrical events definitely precede the actual mechanical contraction of the heart. This type of observation forced early investigators to conclude that electrical currents that produce

TABLE II

TABLE FOR CALCULATION OF HEART RATE

(The Following Table Can Be Used if the Rhythm Is Regular)

Length of cycle in 1/25 sec	*Rate per min*	*Length of cycle in 1/25 sec*	*Rate per min*	*Length of cycle in 1/25 sec*	*Rate per min*
5	300 0				
5½	272 7	20½	73 2	35½	42 2
6	250 0	21	71.5	36	41 7
6½	230 8	21½	69 8	36½	41 4
7	214 3	22	68 2	37	40 6
7½	200 0	22½	66 7	37½	40 0
8	187.5	23	55 2	38	39 5
8½	176 5	23½	63 8	38½	39 0
9	166 7	24	62 5	39	38 5
9½	157 9	24½	61 2	39½	38 8
10	150 0	25	60 0	40	37 5
10½	142 9	25½	58 8	40½	37 0
11	136 4	26	57 7	41	36 6
11½	130 4	26½	56 6	41½	36 1
12	125 0	27	55 6	42	35 7
12½	120 0	27½	54.5	42½	35.3
13	115 4	28	53 5	43	34 9
13½	111 1	28½	52 6	43½	34 5
14	107 1	29	51 6	44	34 1
14½	103 4	29½	50 8	44½	33 7
15	100 0	30	50 0	45	33 3
15½	96 8	30½	49 2	45½	33 0
16	93 8	31	48 4	46	32 6
16½	90 9	31½	47 6	46½	32 3
17	88 2	32	46.9	47	31 9
17½	85 7	32½	46.2	47½	31 6
18	83.3	33	45.5	48	31 3
18½	81 1	33½	44 8	48½	30 9
19	79 0	34	44 1	49	30 6
19½	76.9	34½	43.5	49½	30.3
20	75 0	35	44 1	50	30 0

the waves of the electrocardiogram are not produced by the actual muscle contraction but are the result of some process in the muscles that precedes and in some way prepares the muscles for contraction. This somewhat hypothetical process is referred to as the excitation wave or process. This view has never been entirely abandoned but Einthoven[6] did greatly reduce the time interval between the electrical and mechanical events by more refined instruments.

Note: The normal and abnormal features of precordial leads are discussed together on pages 630 and 631.

IV. ABNORMALITIES AND VARIATION OF THE INDIVIDUAL WAVES IN THE LIMB LEADS AND CERTAIN TIME INTERVALS

A. The P Waves: (*a*) *Decrease in amplitude* of the P wave is observed in cases of vagal stimulation, *e.g.*, after carotid sinus pressure, as a result of digitalis and spontaneously, especially in Lead III, during slowing of the heart at the end of expiration. At times, it occurs without reason in hearts that are apparently normal. In some or all of these circumstances, it may be due to the shifting of the pacemaker from the *head to the tail of the sinoauricular node.* Decrease in amplitude has also been observed in hypothyroidism and myxedema, and we have observed this in cases of auricular dilatation and hypodynamic states of the auricle.

While the change may at times result from disease, actually the finding has little or no practical value

(*b*) *Increase in amplitude of the P wave.* This occurs in some but by *no means all cases of auricular disease, particularly in mitral stenosis, in* such cases the P wave is usually notched and its base broadened. Increase in amplitude without widening of the auricular complex occasionally is seen in hypertensive hearts and as a result of toxemia. This sign is not of great value. This is so because it is difficult to know where the normal ends and the abnormal begins.

(*c*) *Inversion of the P Wave:* One of the factors that determines the *shape of a wave is the direction the contraction process follows through* the muscle. When the impulse arises in the sinoauricular node and follows the usual direction through the auricular muscle, the resulting P wave is upright. When the origin of the impulse is definitely away from the sinoauricular node, the course followed through the auricular

muscle is an abnormal one, and the resulting P wave is inverted or at least differently shaped from the normal P wave Since an abnormal or ectopic site of origin of the impulse is the essential feature of such disturbances as auricular extrasystoles, auricular paroxysmal tachycardia and A V nodal rhythm (Figs 14 *E* and 19 *A* and *C*) inversion of the P wave is usual in these arrhythmias It is also present in the rare instance of

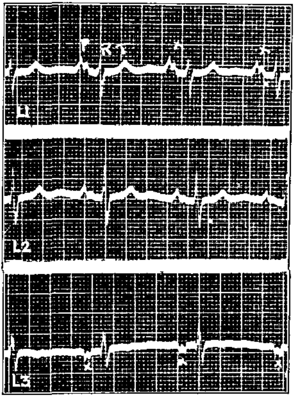


FIGURE 3 Notched P waves The P waves in Lead I are markedly notched and their base is quite broadened. Such P waves are almost always a result of rheumatic disease of the auricular muscle

retrograde beats where ventricular impulses are transmitted backward through the junctional structures to reach the auricles

While inverted P waves always suggest and usually result from an ectopic origin of the impulse it must be remembered that there are exceptions Inversion of the P waves in Lead III is common and has no significance (Fig 2 *C*) Occasionally it occurs in Lead II and even in Lead I without any demonstrable cardiac abnormality When it results from an ectopic origin this change will be accompanied by some irregu

larity as in auricular extrasystoles or by some change in the rate as in auricular paroxysmal tachycardia and nodal rhythm

The change is therefore of considerable significance usually but at times may have no practical meaning The latter is always the case when the change is confined to Lead III

(*d*) *Notching of the P wave* of slight or moderate degree is a sign usually thought to be of no great importance since it is said to frequently occur in nondiseased hearts Notching in Lead III alone is undoubtedly seen frequently with normal hearts and therefore of no significance The same is true to a lesser extent when the change is present in Lead II alone or in Leads II and III *When the P wave of Lead I is definitely and unmistakably notched auricular muscle disease is nearly always present* (Fig 3) *The most frequent cause of the latter is the acute* myocardial involvement of rheumatic fever or the later chronic stage Less commonly notching develops in hypertensive arteriosclerotic and luetic heart disease and occasionally is produced by the toxic effects of digitalis and quinidine sulfate

(*e*) *Absence of P waves* Unquestionably the commonest condition causing absence of P waves is auricular fibrillation where these waves are replaced by small oscillations referred to as f waves which occur at the rate of from 400 to 600 per minute (Fig 17) In a closely allied condition auricular flutter there are no P waves strictly speaking but a series of regular fairly large oscillations occurring at a rate of from 2?0 to 370 per minute In A V nodal rhythm arising in the middle portion of the A V node the P wave is not seen but of course is not absent as it occurs synchronously with and is therefore hidden by the Q R S complex (Fig 19 *B*) In intraauricular block and auricular standstill the P waves are also absent the former has been reported as a toxic quinidine effect and the latter has been observed during syncopal and Stokes Adams seizures *Neither condition is common*

B Abnormalities of the P R Interval The P R interval is measured from the beginning of the upstroke of the P wave to the beginning of the Q wave it normally varies from 0 12 to 0 18 second Values above 0 20 and below 0 08 are considered abnormal When the P R interval exceeds 0 20 of a second the earliest grade of A V heart block is present (Fig 18 *A*)

The P-R *interval is shortened in cases of upper nodal rhythm* and nodal extrasystoles (Fig. 19). It is also shortened in the presence of a recently described rhythm consisting of short P-R intervals with prolonged Q-R-S complexes occurring in healthy young people prone to paroxysmal tachycardia[12, 13] (Fig. 4). It may appear to be shortened at times when the auricles and ventricles are beating independently as in complete A-V block and ventricular escape. This is of course not a true shortening of the P-R interval. In these instances the occasional

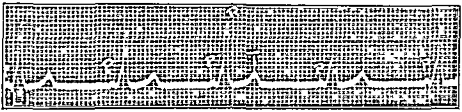


FIGURE 4. Short P-R intervals with widened Q-R-S complexes. This combination of findings is not very common, but is seen in apparently entirely healthy individuals. Auricular paroxysmal tachycardia is a very frequent accompaniment.

close proximity of the P wave and the Q-R-S complex is entirely accidental; it does not control and is not related to the Q-R-S complex which follows.

C. Abnormalities of the Q-R-S Complexes: (*a*) *Prominent Q waves:* The Q wave, if present in Lead I, usually measures 1 to 3 mm. An increase in amplitude of the Q wave to 4 or 5 mm. with a rather tall Q-R-S complex is observed in some cases of hypertension with left ventricular hypertrophy. An increase in amplitude of Q_1 either absolute or relatively in proportion to the height of the R wave is frequently observed in an acute anterior myocardial infarction (Q_1 T_1 type) which involves the anterior portion of the interventricular septum. This wave may remain permanently (Fig. 5 *A*).

A Q wave in Lead III may be observed in entirely normal individuals whose diaphragms are elevated. It is frequently produced by this mechanism as a transient event in pregnancy. Since moderate degrees of right axis deviation are sometimes present in normal hearts, small Q waves in Lead III present in this association have no pathologic significance (Fig. 2 *C*). When Q waves are present with undiseased hearts, this wave usually does not exceed 25 per cent of the amplitude of the ventricular complex[14] and is usually materially decreased or made to disappear

entirely by deep inspiration. A Q wave exceeding the amplitude of the Q-R-S complex in Lead III by 25 per cent or more (except in right axis deviation) is observed in the following conditions: In the acute stage of posterior myocardial infarction (Q_3-T_3 type) (Fig 24), in hypertension, angina pectoris or coronary artery disease[15] In cases of infarction it is believed to be due to involvement of the posterior portion of the interventricular septum.[16] In the latter, it is often associated with a

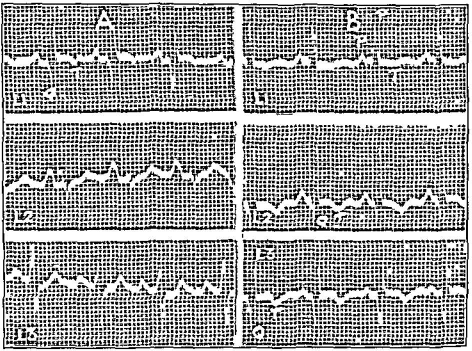


FIGURE 5 Prominent Q waves not associated with acute coronary occlusion In *A* the Q waves of Lead I are quite prominent In *B* the Q waves of Leads II and III are prominent Such Q waves are frequently a manifestation of severe myocardial disease In both cases illustrated, the history suggests that there may have been an acute coronary occlusion at some time in the past The Q waves in both instances are permanent changes

prominent Q wave in Lead II and definite abnormality of the T waves and S T segments in Leads II and III. in the stage of acute infarction the S T segment is elevated, later the T wave becomes inverted and with healing often becomes upright. While it often persists (Fig 5 *B*), a prominent Q_2 and Q_3 often diminishes and may entirely disappear with healing of the infarct

(*b*) *Abnormalities in amplitude of the Q R-S complexes* 1. INCREASED AMPLITUDE: Increased height of the Q R-S complexes in an upright direction may not be of great consequence unless it is considerable Markedly

The P R interval is shortened in cases of upper nodal rhythm and nodal extrasystoles (Fig. 19) It is also shortened in the presence of a recently described rhythm consisting of short P R intervals with prolonged Q R S complexes occurring in healthy young people prone to paroxysmal tachycardia[12, 13] (Fig 4). It may appear to be shortened at times when the auricles and ventricles are beating independently as in complete A-V block and ventricular escape. This is of course not a true shortening of the P R interval. In these instances the occasional

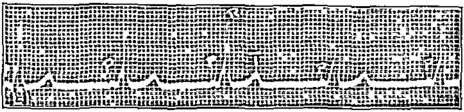


FIGURE 4 Short P R intervals with widened Q R S complexes This combination of findings is not very common but is seen in apparently entirely healthy individuals Auricular paroxysmal tachycardia is a very frequent accompaniment

close proximity of the P wave and the Q-R S complex is entirely accidental, it does not control and is not related to the Q R S complex which follows

C. **Abnormalities of the Q-R-S Complexes:** (*a*) *Prominent Q waves* The Q wave, if present in Lead I, usually measures 1 to 3 mm. *An increase in amplitude of the Q wave to 4 or 5 mm. with a rather tall* Q R S complex is observed in some cases of hypertension with left ventricular hypertrophy An increase in amplitude of Q_1 either absolute or relatively in proportion to the height of the R wave is frequently observed in an acute anterior myocardial infarction (Q_1 T_1 type) which involves the anterior portion of the interventricular septum This wave may remain permanently (Fig 5 *A*)

A Q wave in Lead III may be observed in entirely normal individuals whose diaphragms are elevated It is frequently produced by this mechanism as a transient event in pregnancy Since moderate degrees of right axis deviation are sometimes present in normal hearts, small Q waves in Lead III present in this association have no pathologic significance (Fig 2 C) When Q waves are present with undiseased hearts, this wave usually does not exceed 25 per cent of the amplitude of the ventricular complex[14] and is usually materially decreased or made to disappear

entirely by deep inspiration. A Q wave exceeding the amplitude of the Q R S complex in Lead III by 25 per cent or more (except in right axis deviation) is observed in the following conditions: In the acute stage of posterior myocardial infarction (Q_3T_3 type) (Fig. [illegible]), in hypertension, angina pectoris or coronary artery disease.[15] In cases of infarction it is believed to be due to involvement of the posterior portion of the interventricular septum.[16] In the latter it is often associated with a

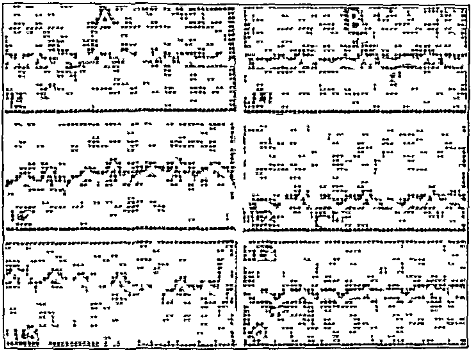


FIGURE 5[illegible] Q waves associated with coronary occlusion [illegible] Q waves of Lead I are quite prominent [illegible] In B the Q waves of Leads II and III are prominent. Such Q waves are frequently a manifestation of severe myocardial disease. In both cases illustrated the history suggests that there may have been an acute coronary occlusion at some time in the past. The Q waves in both instances are permanent [illegible]

prominent Q wave in Lead II and definite abnormality of the T waves and S-T segments in Leads II and III. In the stage of acute infarction the S-T segment is elevated, later the T wave becomes inverted and with healing often becomes upright. While it often persists (Fig. 5[illegible] B), a prominent Q_2 and Q_3 often diminishes and may entirely disappear with healing of the infarct.

(*b*) *Abnormalities in amplitude of the Q R-S complexes.* 1. INCREASED AMPLITUDE. Increased height of the Q R S complexes in an upright direction may not be of great consequence unless it is considerable. Markedly

high amplitudes in certain leads are observed in the presence of left ventricular hypertrophy, usually associated with hypertension.

2. Low amplitude: Decreased height of the ventricular complexes is often of significance. Abnormally low amplitude is said to exist when the height of the ventricular complexes is no more than 5 mm. in either of the three customary limb leads (Fig. 6). It is of no significance when

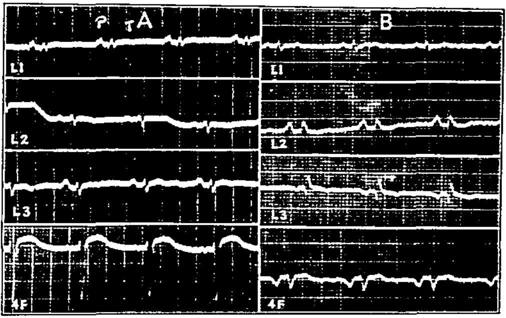


Figure 6 Low amplitude of the Q R S complex In both *A* and *B*, the Q R S complexes are low in all indirect leads The patient, illustrated in *A*, had marked edema, which probably contributed the low amplitude. The patient, illustrated in *B*, had no striking edema. Note that with low amplitude of the ventricular complexes in the limb leads, the amplitude in the chest lead may be either normal or diminished, depending on the cardiac condition that is present.

low amplitude is present in one lead only (Fig 2 *D*). The importance of low amplitude in all leads must be regarded as equivocal since it not infrequently exists in at least moderate degrees, in persons with normal hearts, especially when there is accompanying obesity. Generally, however, this change is associated with and is a result of some forms of cardiac abnormality. Its usual cause is myocardial failure accompanied by edema. as a result of which the heart current is widely dissipated and less voltage reaches the string of the galvanometer. Low amplitude also is seen at times in myocardial disease without much edema and is also associated occasionally with edema of noncardiac origin.[17] When low amplitude curves are the result of edema, the change is often reversible, the normal

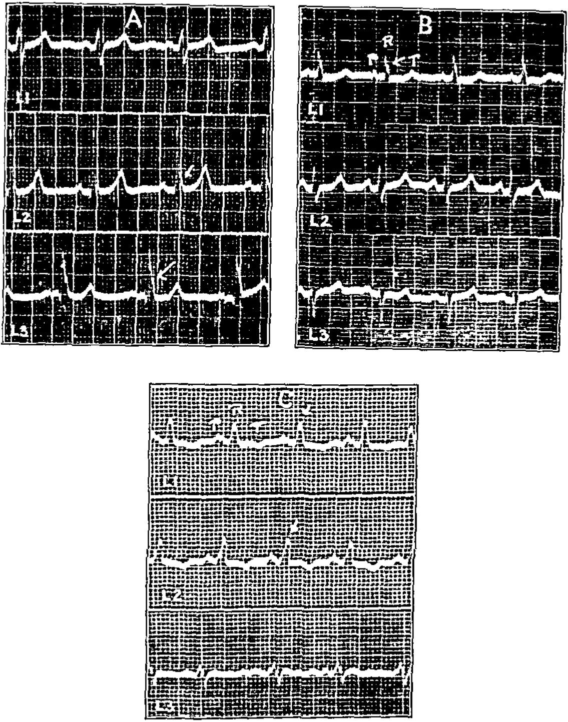


FIGURE 7 Notching of the Q R S complex Notching is of no significance when confined to Lead III, *A* It may have no significance when it occurs near the base line even in Lead II or Lead I Definite notching at the apex of the ventricular complexes as shown in *C* strongly suggests myocardial disease In *B*, the notching in Lead I is neither at the base line nor at the apex The significance of such notching is sometimes uncertain

amplitude returning with the disappearance of the excessive tissue fluid. Other conditions in which low amplitude complexes occur are myxedema and pericardial effusion. Abnormally low amplitude of the ventricular complexes (below 5 mm.) may be present in Lead II alone, in the presence of left or right axis deviation and in right and left bundle branch block. The change has no significance under these circumstances unless the low amplitude complex in Lead II is bizarre. Small bizarre complexes shaped like the letter M or W are usually seen in patients with coronary disease and angina pectoris.[18]

(*c*) *Slurring and notching of the Q-R-S complexes* not accompanied by widening, are not abnormal or suggestive of disease when confined to Lead III (Fig. 2 *E*); it may have no significance even when it is present in Leads I and II if it is located near the base line (Fig. 7 *A*) or if the amplitude of the Q-R-S complexes is diminished (Fig. 7 *B*). However, if present near the apex of the Q R S complexes in Leads I and II when these complexes are at least moderately large, it is usually the result of some myocardial abnormality (Fig. 7 *C*). Notching of the Q R-S complexes is of course, a common and almost essential feature of ventricular extrasystoles, intraventricular and bundle branch block. In these conditions, however, there is accompanying widening of the Q R S complexes.

(*d*) *Alternation in amplitude* of successive Q R-S complexes without other changes in the complex (true electrical alternation) is quite rare with normal heart rates With abnormally rapid rates (*e.g.*, paroxysmal tachycardia) the finding is not uncommon (Fig. 15). It may be associated with other manifestations of electrical alternation, *e.g*, alternation of the *P* R interval or the height of the *T* wave. It may or may not be associated with mechanical alternation as manifested in the radial pulse.

(*e*) *Widening of the Q-R-S complexes*· Study of large numbers of tracings has shown that in the majority of normal individuals, the width of the Q R-S complexes varies between 0 06 and 0.08 second, and that a width greater than 0 10 second generally indicates some myocardial abnormality However, it is to be remembered that this small interval is sometimes difficult to measure and may be increased by improper technic. *Therefore one should be quite certain that real widening is present before any diagnosis is made on this finding alone.* Definite increase in width of the Q-R S must indicate an asynchronous activation of the two ven-

tricles it is present mainly in ventricular extrasystoles and in paroxysmal ventricular tachycardia and in bundle branch block In the latter condition, the ventricular complexes should be definitely widened It has been stated on sound grounds that the Q R-S complex is at least 0 14 second in duration in definite complete bundle branch block However lesser grades of widening (between 0 10 and 0 14 second) represent disease They may be produced by varying grades of intraventricular conduction defects by ventricular hypertrophy or by a combination of these factors True bundle branch block should not be diagnosed in the presence of a high ventricular rate in which case the widening may be due to fatigue in the sense that the diminshed rest period incident to the rapid rate brings into play a potential defect in the conduction system which is quiescent so long as there is sufficient time between contractions for rest and recovery In some instances bundle branch block may result from toxic factors or acute disease of the muscle and may be reversible as recovery or healing takes place

The alterations in the Q R S complexes occurring in ventricular extrasystoles, ventricular tachycardia and ventricular fibrillation will be discussed with these arrhythmias

D *The Electrical Axis* *Since this subject has been fully discussed* and illustrated in Chapter XXVII we are not showing illustrations of this disturbance The ventricular electrocardiogram is composite in the sense that it represents the superimposed electrical effects developed by both the right and left ventricles In a normal heart these effects are such that the R wave of the electrocardiogram is the conspicuous wave in all three leads and is taller in Lead II than in either Leads I or III Such an arrangement constitutes what Lewis[9] called a bicardiogram Not infrequently one encounters patterns altogether different That in which the R wave is taller in Lead I than it is in Lead II while in Lead III the S wave is more conspicuous than the R wave has been called by Lewis a levocardiogram since this is the type of curve that is so frequently associated with left ventricular hypertrophy and was thought by him to be the result of a preponderance of the electrical effects of the left ventricles (Fig 8) A pattern in which the R wave is taller in I and III than it is in Lead II and in which the S wave is more conspicuous in Lead I than the R wave for similar reasons, was designated by Lewis as a dextro

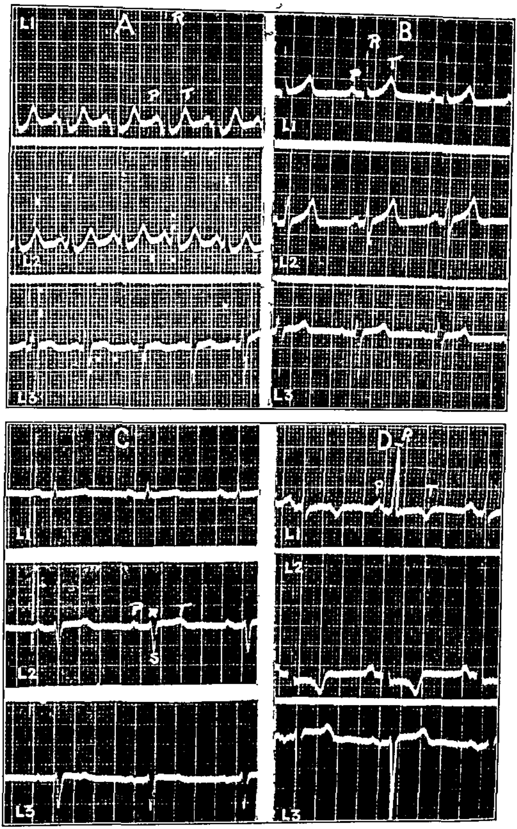


FIGURE 8 Left axis deviation Note that this change may be associated with either upright or inverted T waves There is usually but not always a Q wave in Lead I In *C*, note the R wave in Lead I and the prominent S wave in Lead II Either with or without inverted T waves, this configuration is probably always significant of myocardial disease.

cardiogram* (Fig. 9). In order to discuss the factors that are responsible for these differences in pattern, it is necessary to consider the electrical axis of the heart Since this has been fully discussed in Chapter XXVII it will not be considered here at length.

Suffice it to say that the electrical axis of the heart may be defined as the *line along which the greatest electromotive forces are developed*

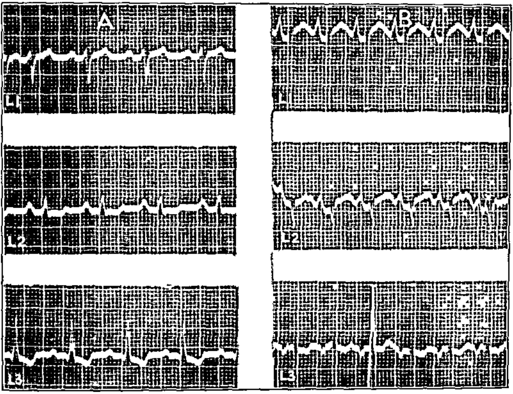


FIGURE 9 Right axis deviation The tracing under *A* is from a case of mitral stenosis. That under *B* is from a case of congenital pulmonary stenosis In the latter note the large amplitude of the ventricular complexes and their diphasic character in Leads I and III. This has been said to be characteristic of congenital disease accompanied by right ventricular hypertrophy [22]

at a given instance of time when the muscle is entering upon or recovering from the excitatory process This is, of course, rather complex since it is obvious that in a spherical body like the heart, the charge may be developed along many planes The direction can, however, be related to one plane, the frontal plane *of the chest, and calculated from data* obtained from the three leads of the electrocardiogram

* The terms levocardiogram and dextrocardiogram are used purely in a descriptive sense We are using them as Lewis originally meant them because they are more familiar in that sense

The position of the electrical axis determines the shape of the ventricular complexes in the three leads. Normally it points downward and slightly to the left, forming an angle of 70° (on the average) with a line drawn through the shoulders (the base of Einthoven's triangle). When this is the case, the Q-R-S complexes in the three leads take the form of what Lewis described as a bicardiogram. When the axis is deviated counterclockwise to the left until it points above a line drawn through the shoulders, the ventricular complexes in the three leads assume the characteristics of Lewis' levocardiogram. When the axis is deviated clockwise from its normal 70° to the right until it forms an angle of more than 90° with a line drawn through the shoulders, the ventricular complexes assume the configuration of a dextrocardiogram as described by Lewis.

(*a*) *Left axis deviation* is observed in the following conditions·

1. Left ventricular hypertrophy is the commonest cause of the left axis deviation. In normal hearts, the left ventricle weight is, on an average, 1 8 times that of the right ventricle. This relationship is disturbed in any condition tending to cause left ventricular strain and consequent hypertrophy, *e.g.*, hypertension, aortic insufficiency and aortic stenosis. The increase in the relative weight of the left ventricle produces a left axis deviation. The electrocardiogram in this condition shows a tall R in Lead I with little or no S[1] and a deep S with little or no R in Lead III.

2 In anterior myocardial infarction, a left axis deviation is often produced early, even in the absence of obvious left ventricular hypertrophy. This is probably the result of a preponderant spread of the excitation wave to other portions of the left ventricle as the result of the infarction of the anterior wall. In such cases, a small R wave is present in Lead I and a deep S wave in Lead III

3. A transverse position of the heart due to a high diaphragm or during a deep expiration may result in a left axis deviation, but the degree of this type of axis deviation is never marked.

4. Shifting of the heart on its vertical axis toward the right [10] This may result from various pathologic conditions in the chest and in some instances may be produced by having the patient lie on the right side.

5. In left bundle branch block (common type).* The Q R S complexes will be widened.

* In view of the recent work concerning the site of bundle branch block, the old theories of its production as originally suggested by Lewis, must be revised The suggestion is made by Wilson[20] that the presence of a left axis deviation in the common type of bundle branch block and right axis deviation in the rare type of bundle branch block is due to the summation of the electrical forces between the interventricular septum and free wall of the left ventricle

6 In right ventricular premature contractions[20] and in ventricular extra systoles arising near the base of the heart there will be accompanying widening of the Q R S complexes

7 *In some cases particularly in small hearts weighing less than 250 Gm* no obvious cause for the axis deviation can be ascertained[21]

1 SIGNIFICANCE OF DEEP S WAVES IN LEAD II WITH LEFT AXIS DEVIATION A deep S wave in Lead II that is much greater in amplitude than the preceding R wave is associated with an abnormal type of left axis deviation and is a sign of considerable importance (Fig 8 C) It is observed in the following conditions In myocardial disease involving the left ventricle it has been seen particularly in cases of anterior myocardial infarction during the acute and healed stage in hypertension aortic insufficiency angina pectoris and arteriosclerotic heart disease[28] This finding is of some significance though the electrocardiogram may be otherwise normal

(*b*) *Right axis deviation* is observed in the following conditions

1 A slight grade of right axis deviation is normally present in the first few months of life and may persist into early adult life (Fig 2 4)

2 Right ventricular hypertrophy is the commonest cause of right axis deviation It is produced by any factor that produces a strain and consequent relative hypertrophy of the right ventricle Mitral stenosis is the most important cause It is also seen in right ventricular hypertrophy by occurring in congenital heart disease Other conditions tending to produce right ventricular hypertrophy and consequent right axis deviation are chronic pulmonary fibrosis emphysema multiple pulmonary infarction and pulmonary arteriosclerosis

3 Rarely *right axis deviation is observed* following anterior myocardial infarction

4 A vertical position of the heart may give rise to a slight grade of right axis deviation and it may be produced by deep inspiration but the degree is never marked

5 Shifting of the heart on its vertical axis toward the left may occur consequent upon various pathologic conditions in the chest This occurs frequently in the presence of mitral stenosis It may be produced in some instances by having the patient lie on the left side

6 The uncommon type of bundle branch block (right) The Q R S complexes will be widened

7 In left ventricular premature beats there will also be widening of the Q R S complexes

8 In congenital dextrocardia there is a complete inversion of all the complexes in Lead I and an interchange of the usual Leads II and III

E Abnormalities of Q T Interval* (*a*) *Lengthening of the Q T Interval* Lengthening of the Q T interval is of considerable importance from the diagnostic and prognostic standpoint Knowledge concerning its significance has been arrived at only recently Lengthening of this interval is observed in hypocalcemia (Fig 10 *B*) during emergence from diabetic acidosis (Fig 10 *A*) in azotemia in alkalosis during hypogly

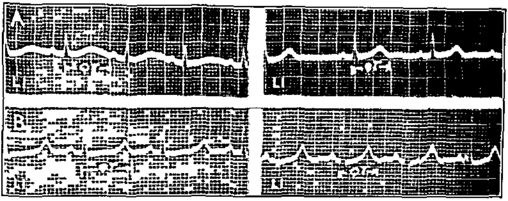


FIGURE 10 Prolongation of the Q T interval The tracings under *A* were obtained from a patient with diabetic acidosis The first strip was made shortly after emergence from coma The second strip was obtained a week later *B* shows strips of tracings from a patient with hypocalcemia The first strip was made at the height of the disturbance the second strip after the blood calcium had returned to a normal level

cemic shock and in various types of myocardial disease (*e g* myocardial infarction toxic states in avitaminosis) and as a result of the action of certain drugs (quinidine) This lengthening is often reversible the normal Q T is restored with return of the diseased process to normal

(*b*) *Shortening of the Q T interval* is observed in hyperparathyroidism and as a result of the action of digitalis In the latter condition it is accompanied by characteristic depression of the S T interval

F Abnormalities of the T Wave (*a*) *Variation in Amplitude* The T wave is increased in amplitude following exercise occasionally in thyrotoxicosis in bundle branch block and in ventricular extrasystoles During the subacute stage of myocardial infarction and in patients with severe anginal seizures the amplitude of the T wave particularly in the chest leads may be considerably increased This is of practical diagnostic import

* See table I p 611 for normal Q T values

Decrease in amplitude of the T wave below 2 mm in Leads I and II with normal amplitude of Q R-S is usually due to myocardial derangement (Fig 8 C) It is to be remembered that digitalis and toxic states as well as disease of the heart can produce this change In hypothyroidism and myxedema as well as generalized edema not only are the T waves low but decrease in amplitude of the Q R S complexes is also present It is to be remembered also that a low amplitude T wave associated with a low Q R S complex is sometimes observed in patients with dropped or ptotic hearts which are essentially normal *Moderate lowering of the T waves should be interpreted carefully and conservatively*

Isoelectric or flat T waves are due to factors similar to those mentioned under decreased amplitude

(*b*) *Diphasic T waves* refers to a configuration in which part of the T wave is inverted and part upright In some instances the first portion is inverted while the terminal part of the T wave is upright In other instances the first part is upright and the terminal portion inverted Diphasic T waves generally represent a stage between normally upright T waves and completely inverted waves Diphasic T waves therefore have in somewhat lesser degree the same significance that applies to inverted waves

The term diphasic is often loosely applied to a configuration in which the T wave proper is entirely upright but the S T line is depressed Such a pattern may be produced by digitalis[22] or by acute myocardial infarction as well as other factors It is better to refer to this configuration as deviation of the S T segment

(*c*) *Notching of the T Waves* These waves are as a rule rounded and smooth Not infrequently they may appear to be notched as a result of a superimposed P wave as sometimes occurs in paroxysmal tachycardia and A V heart block Occasionally the T waves are genuinely notched It has been recently suggested that this results from a pronounced U wave which closely follows the T wave [23]

(*d*) *Inverted T Waves* At least three types of T wave inversions may be described

1 The Coved T Wave When typical the S T line preceding the inverted T wave is markedly convex upward and usually rises above the base line As shown by Pardee [24] it usually is present in acute or sub

acute myocardial infarction (Fig. 22 *B*). However, it is seen occasionally in other conditions.

2. THE BEAKED T WAVE: The S T line rises slowly and may be slightly coved. At the very end, it dips downward suddenly, making the last portion of the T wave inverted. This type of inversion has the same significance that is attached to the other types of inversion, in the sense that it is associated with severe myocardial derangement. We have seen it particularly in the subacute and acute stage of myocardial infarction, in severe luetic heart disease, in the subacute stage of pericarditis and in patients emerging from diabetic acidosis.[25]

3. THE USUAL INVERTED T WAVE OF MYOCARDIAL DISEASE: While these waves may vary greatly in the depth of inversion, etc, they have this constant characteristic: The S T segment and descending limb of the T wave is always concave upward to some extent. The latter may be slight or it may be marked and at least approach real coving. Generally, this variety of T wave is the result of severe and permanent myocardial change. Occasionally they may be the result of remediable causes such as myxedema, avitaminosis, acidosis, etc and, therefore, may be reversible (Fig. 7 *C*).

The first two types of inverted T's may be considered to be "T waves in flux," *i. e.*, they are due to conditions that are rapidly changing and are rarely observed for more than a few weeks or months. The third type, the myocardial T wave, may be a permanent event since it usually results from forms of myocardial disease that are not likely to improve.

Regardless of the types, inversion of the T waves in Lead I or Leads I and II is always an indication of serious myocardial disease or serious myocardial derangement. Inversion in Lead II is due, perhaps, usually *to myocardial disease. However, not infrequently it is seen in* hearts that present no clinical evidence of myocardial disease. It therefore does not warrant a diagnosis of myocardial disease unless there is something in the examination to confirm its importance.

G. Deviation of the S-T Segment:* A single contraction of a normal *muscle produces an electrocardiogram* which consists of two distinct portions; hence it is diphasic. In the case of the ventricles of the human heart, the first phase is the Q-R-S complex; the second phase is the

* Actually small deviations of the S-T segment are not significant; they may occur in normal hearts. To be suggestive, by itself, the deviation must be more than 2 mm.

T wave. The interval separating these two phases is called the S-T line or R-T segment. In a strictly diphasic curve it is essential that the S-T line arise from the S wave at the base or isoelectric line. When this is not the case and the S-T line comes off definitely above or below the isoelectric line, the S-T segment is said to be deviated. This results in an electrocardiogram that at least tends to be monophasic.

Monophasic type curves, that is to say curves in which the S-T line is definitely deviated, are among the most important findings revealed by the electrocardiogram for the reason that monophasic curves are the

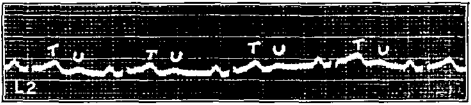


FIGURE 11. U waves. These are usually considered to be of no significance.

result of currents of injury, which in turn are produced in the human heart chiefly by coronary occlusion. The recognition of monophasic curves is the essence of the electrocardiographic diagnosis of coronary occlusion, the field in which this graphic method is at its brilliant best.

One also encounters S-T deviations in other conditions. It may be prominent in pericarditis where it probably results from accompanying muscle injury. It is also produced by digitalis and in certain types of anoxia; the mechanism of its production in these conditions is not so clear.

H. U Waves. *The U wave is an upward peak occurring after the* T wave, often observed in normal tracings (Fig. 11). We did not describe it as a part of the normal electrocardiogram since it is not a constant feature. It usually is considered to occur during ventricular diastole. However Einthoven[98] was of the opinion that this wave indicates persistence of contraction in some fibers into early diastole. The U wave has an amplitude usually of 1.5 mm., begins 0.04 second after the end of the T and continues for 0.16 to 0.24 second with an average duration of 0.20 second. No significance has been attached to the wave. Recently, however, Nahum and Hoff[23] have suggested that the U wave is part of the ventricular complex, is produced during systole and represents the supernormal period of recovery. This is a short period immedi-

ately following recovery from electrical excitation when the ventricle is most susceptible to ectopic beats. They believe that the majority of extrasystoles fall on the U wave or the part of the cycle where it occurs. They found inversion of the U wave or fusion of the U wave with the T wave only in patients with damaged hearts.

V. PRECORDIAL LEADS

Precordial leads are now used routinely, in addition to limb leads, in many conditions They are of particular value in the diagnosis of

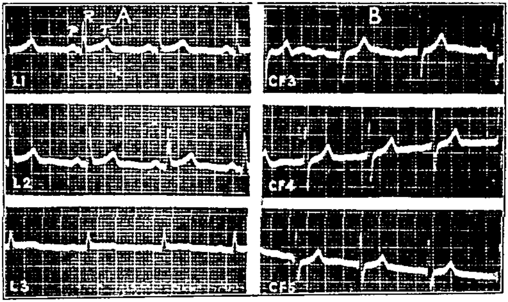


FIGURE 12 Normal limb and chest leads In *A*, all the three customary limb leads are shown. In *B*, three chest leads are illustrated As a rule, all of the numerous chest leads are not made routinely The three illustrated serve nicely for routine purposes

coronary occlusion, pericarditis, digitalis effects and various types of myocardial disease, particularly involving the left ventricle. The precordial leads differ normally within rather wide limits. The variation depends upon the configuration of the heart, its position, and the placement of the precordial electrode. In comparing different tracings on the same patient, it is important that this electrode be placed in the same position

A. THE NORMAL PRECORDIAL LEADS*

With the exploring electrode placed at the apex (IV_F or IV_R), the precordial leads in normal hearts show an initial upward deflection

* Refer to p 605 for chest lead nomenclature

(R wave) followed by a downward deflection (S wave) These are often of about equal amplitude the R wave should be above 4 to 5 mm in height (Fig 12) If the R wave is absent or very small 1 to 2 mm it *is indicative of some abnormality*

The Q R S is usually slightly wider in precordial than in limb leads it may approach 0 1° second in width Slurring may occasionally occur *in the presence of normal hearts* *The T waves are upright in adults* occasionally they may be diphasic In children they may be inverted R S T deviations up to 2 mm may be normal

CFiv closely resembles IV_F in CFiii the R wave is smaller than in CFiv and the S wave larger at times no R wave is present In CFv the R wave is larger the S wave smaller than in CFiv the S wave is frequently absent in Lead CFv Characteristic chest leads (CFiii CFiv CFv) are shown in Fig 12

B ABNORMALITIES IN THE PRECORDIAL LEADS

The initial upward deflection (R wave) is absent in IV_F in the acute and usually in chronic stages of anterior myocardial infarction It is small (1 to 2 mm) and is sometimes entirely absent in severe myocardial disease (other than actual coronary occlusion) involving the left ven *tricle e g hypertension luetic heart disease in dilatation of the left* ventricle in marked right axis deviation and in left bundle branch block

The T wave may be inverted in IV_F in the presence of myocardial disease It closely mirrors the direction of the T wave of Lead I An inverted T wave in Lead IV_F may be the only electrocardiographic abnor mality noted in the tracing in patients with angina pectoris

Diphasic T waves are to be interpreted with caution They may occur in normal hearts

Deviation of the S T segment about 3 mm is usually abnormal Its significance is discussed under other headings

While most cases with anterior myocardial infarction show the most marked changes when the anterior electrode is placed at the apex (IV_F) in some the most marked change occurs when the precordial electrode is placed halfway between the sternum and left mid clavicular area (CF 1) In posterior and in left lateral infarction the most striking R S T interval deviations in chest leads are seen as a rule when the pre cordial electrode is placed in the anterior axillary line (CF_V)

VI. THE ARRHYTHMIAS

Before discussing the arrhythmias, we would like briefly to refer to some of the important features of the normal cardiac mechanism.

A. THE NORMAL MECHANISM

All portions of the heart muscle, including the nodes and specialized conducting tissue, possess certain fundamental properties. While these properties are common to all heart muscle, certain properties are more highly developed in certain parts of the muscle than in others.

For example, excitability and rhythmicity are more highly developed in the muscle fibers that constitute the sinoauricular node. For this reason this structure is the normal pacemaker of the heart, with a normal mechanism impulses arise in this structure quite regularly and at a rate usually between 60 and 120 per minute. From the sinoauricular node, the impulse spreads radially through the auricular muscle at a rate of approximately 1000 mm per second, and in doing so, produces the P wave of the electrocardiogram. The impulse then enters the A-V node. This muscle, like other cardiac muscle, possesses the common fundamental properties but is specialized in that its refractory period is long and its ability to conduct, poor (only 200 mm. per second). Most of the P-R interval is occupied by the passage of the impulse through the A-V node and main bundle of His Having passed these structures, the impulse enters the branches of His bundle and the Purkinje fibers where its passage is rapid (4000 mm per second) since the ability to conduct is very highly developed in these structures. The impulse then enters the muscle of the ventricles which contracts. Once contraction is completed, the muscle returns to and remains in a resting state until another impulse is generated.

Among the important features of a normal mechanism, therefore, are:

1 Regularity of the formation of sinus impulses and the resulting P wave. The P waves are upright.

2. A rate that is within the normal range (between 60 and 120, approximately).

3. Every P wave is followed by a ventricular response.

4. Every ventricular complex is preceded by and will be a response to a P wave

5 The P R interval is between 0 08 and 0 20 second.

6 The impulse reaches both ventricles simultaneously and the Q R S complexes are of normal duration

When any of these features are departed from, the mechanism is no longer normal. Such a departure constitutes a cardiac arrhythmia.

B. CLASSIFICATION OF ARRHYTHMIAS

The arrhythmias may be divided into four groups, according to the portion of the heart in which they arise.

(a) Disturbances of Rhythm Originating in the Sinoauricular Node: Sinus arrhythmias, sinus bradycardia, sinoauricular heart block and prolonged grades of cardiac standstill.

(b) Disturbances Originating in the Auricles: Auricular extrasystoles, auricular paroxysmal tachycardia, auricular flutter, auricular fibrillation and auricular standstill or intraauricular block.

(c) Disturbances Originating in the A-V Node: A-V heart block (prolonged P-R interval, increasing grades of partial block and complete A-V block), nodal rhythm (may be the result of abnormal function of S-A node), A-V dissociation, ventricular escape, nodal extrasystoles and nodal paroxysmal tachycardia.

(d) Disturbances Arising in the Ventricles: Ventricular extrasystoles, ventricular paroxysmal tachycardia, ventricular fibrillation and pulsus alternans.

C. SINUS ARRHYTHMIA

The usual type of sinus arrhythmia is characterized by a gradual waxing and waning of the cardiac rate which varies with the phases of respiration. The rate increases with inspiration due to a diminution in vagal effects and decreases with expiration as a result of increased vagal action. This type is usually seen in young individuals in whom it is physiologic (Fig. 13 *A*). Another type of sinus arrhythmia is observed *in which this irregularity occurs independently of respiration.* This form is often a result of toxic digitalis effects.

The impulse originates in the normal pacemaker and is transmitted normally through the heart. The only electrocardiographic change is the variation in time between successive auricular (P) waves. This irregularity is abolished by any factor that increases the heart rate, *e.g.*, exercise, emotion or atropine. Its presence carries with it no definite pathologic significance. However, in older patients it is said to be associated with arteriosclerotic process in the heart muscle.

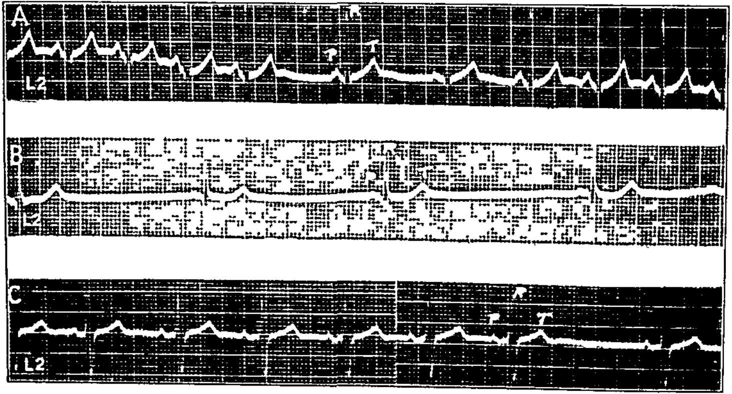


FIGURE 19. Disturbances of the normal sinus mechanism. A, Sinus arrhythmia. Note the marked slowing of the rate of formation of P waves and then the gradual increase in rate. B, Sinus bradycardia. P waves occur fairly regularly but at an abnormally low rate. C, Sinoauricular heart block. Note that the rate of formation of the P waves suddenly becomes halved.

D SINUS BRADYCARDIA

This is characterized by a low sinus rate 40 to 50 per minute No other abnormalities are noted (Fig 13 *B*) Although occasionally observed in young individuals with excessive vagal tone it is more frequently observed in older patients with varying degrees of arteriosclerosis The sinus rate can usually be increased by atropine or other factors which diminish vagal tone

E SINOAURICULAR HEART BLOCK

This is recognized in the electrocardiogram by the fact that the interval between successive P waves is exactly or almost twice the usual P P interval An auricular as well as its accompanying ventricular complex is lost (Fig 13 *C*) Several types of sinoauricular block are observed (1) The irregularity may be observed for a few cycles (2) the rate may be suddenly halved dropping for example from 75 to 36 per minute the slow rate persisting for several minutes or more (3) this disturbance may be present for long periods of time and may be the underlying mechanism for long continued bradycardia

The mechanism of this irregularity is poorly understood It is apparently associated with increased vagal tone and may be abolished by exercise or atropine It carries with it no pathologic significance as a rule However in older patients it is often associated with arteriosclerotic change in the latter type of patient it may also be produced by digitalis effects

F PROLONGED SINUS PAUSES (Cardiac Standstill)

If for any reason the sinus node fails to initiate the cardiac impulse the A V node because it also possesses the property of rhythmicity to a degree only slightly below that of the S A node soon escapes and initiates the heartbeat slowly and rhythmically until the S A node can again resume its function as pacemaker

Ordinarily the A V node is prompt to assume its pacemaker function In certain instances however this may be delayed with the result that there is complete cardiac standstill This may be of sufficient duration to produce dizziness or even syncopal attacks These pauses are the result of vagal effects which may either occur spontaneously as a result of reflex disturbances or be produced in susceptible individuals by carotid sinus pressure Such seizures can usually be abolished by atropine or ephedrine

G. AURICULAR EXTRASYSTOLES

In auricular extrasystoles, the impulse arises prematurely from an ectopic focus in the auricular muscle outside the sinus node. Hence they are frequently referred to as premature or ectopic beats. From its point of origin, the impulse travels to the other portion of the auricular muscle and is then propagated through the A-V node and ventricles in a normal manner. Since the impulse arises from a point outside of the sinus node, it will travel through the auricle in an unusual direction; the P wave therefore possesses an abnormal contour. It may be splintered, notched, diphasic or inverted (Fig. 14 *E*). The P-R interval is usually not shortened. The further the ectopic focus is situated from the sinoauricular node, the more abnormal is the shape of the premature P wave. When, as is frequently the case, the ectopic focus is quite near the sinoauricular node, the premature P wave may be nearly or identically like the normal sinus P wave (Fig. 14, *D* and *F*). The other electrocardiographic feature is, as has been implied, the fact that the P waves occur prematurely.

The pause following the auricular extrasystole is usually not compensatory in the sense that the interval between the normal beats immediately preceding and succeeding the extrasystole is identically the same as the interval between three normal beats. However, there frequently is some pause after the premature beat.

Almost always an auricular extrasystole is followed by a ventricular response. Occasionally, the auricular wave occurs so prematurely that the ventricle will not have recovered sufficiently to respond. Under these circumstances, one sees the very premature P wave without an accompanying ventricular response. The Q-R-S complexes following the premature *P wave is usually of normal contour since the shape of the ventricular* waves is determined solely by the course of the impulse within the ventricles, which in no way is influenced by the site of origin of the impulse within the auricles. If, however, there is some potential defect in one of the branches of the His bundle, the diminished rest period induced by the premature beat may bring this defect into play with the result that the ventricular complex of the auricular extrasystole may be as widened and notched as a ventricular extrasystole. Auricular extrasystoles may occur as isolated beats, coupled to normal beats or in series of two or more. When six or eight of such beats occur in succession they constitute a short paroxysm of auricular tachycardia.

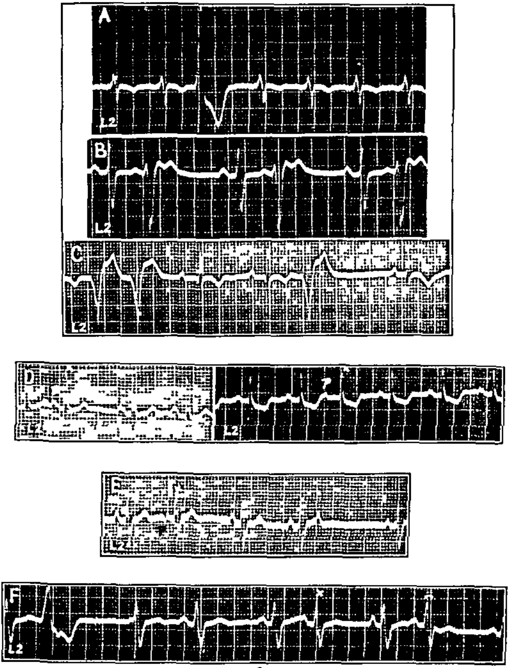


FIGURE 14 Extrasystoles Ventricular extrasystoles are shown in A B and C These complexes are of considerable amplitude are widened and are premature All of those shown are followed by compensatory pauses. In B, note that the ventricular extrasystoles are accurately coupled to preceding normal beats In B note that two ventricular extra systoles *occur in rapid sequence*

Auricular extrasystoles are shown in D E and F Note that the premature P waves are upright in D and F In E, an inverted P wave is shown In E a premature P wave is superimposed on the fourth T wave This premature auricular beat occurs so early that the ventricles cannot respond to it.

The cause and significance of auricular extrasystoles is often difficult to determine. This disturbance is often observed in normal hearts. On the other hand, these premature beats are frequently a result of disease of the auricular muscle. They are not infrequently observed in rheumatic fever, other infections and in hypertensive and arteriosclerotic hearts. *The occurrence of extrasystoles is therefore not pathognomonic evidence of heart disease.* On the other hand, it is somewhat suggestive. Their significance must be determined by other studies.

H. AURICULAR PAROXYSMAL TACHYCARDIA

Paroxysmal auricular tachycardia consists of a rapid succession of auricular extrasystoles. The rate during the paroxysm varies approximately from 140 to 220 per minute (Fig. 15).

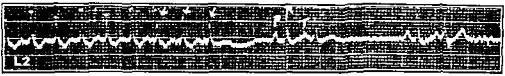


FIGURE 15. Auricular paroxysmal tachycardia. The rate during the disturbance is 200 per minute. Note the end of the paroxysm followed by a postparoxysmal pause with restoration of normal rhythm. The initial cycles of normal rhythm shows coupled auricular extrasystoles. Note also the alternation in the amplitude of the ventricular complexes during the rapid rate. Electrical alternation.

The P waves of the paroxysm show an abnormal form similar to that of an auricular extrasystole. With very rapid rates the P waves are often superimposed on the T wave, making its recognition difficult or impossible. When this is so, the certain identification of the disturbance can be made only if one secures the beginning or the ending of a paroxysm. The Q R S complex is usually normal in shape. In some instances widening of the ventricular complexes occurs, due to fatigue of the intraventricular conducting mechanism incident to the high rates and resulting diminished rest period. Usually the ventricles respond regularly to every auricular impulse. It is not difficult to see how this might not be the case if there is any disease of the A V node or if this structure is strongly under the influence of digitalis. It is not unusual to encounter some degree of A V heart block with auricular paroxysmal tachycardia.

The paroxysms of tachycardia may last from a few seconds to a few days. They start and end abruptly. *There may be a fairly long post-paroxysmal pause* between the ending of the paroxysm and the resumption of normal impulse formation by the sinus node. The paroxysms can

be terminated in a large percentage of instances by pressure over the carotid sinus

No more is known concerning the cause of auricular paroxysmal tachycardia than of auricular extrasystoles *However, it is well established by clinical observation that this disturbance frequently (perhaps usually) developes in individuals with no evidence of organic heart disease* Often persons who have this disturbance for years live to old age without developing any other evidence of cardiac disease While very little is known of the fundamental cause it is well established that the attacks are precipitated often by extracardiac factors particularly gastrointestinal disturbances and nervous or emotional influences

I AURICULAR DISTURBANCES DEPENDENT ON A CIRCUS MOVEMENT

(a) The Circus Movement * With a normal cardiac mechanism an impulse arising at a single point (the S A node) spreads until it has involved the entire muscle With the completion of the contraction thus produced the muscle remains at rest until another impulse arises in the S A node and repeats the process An entirely different type of mechanism known generally as the circus movement exists quite frequently in the abnormal heart and is responsible for two important disturbances of rhythm Auricular flutter and auricular fibrillation With a circus movement the impulse that produces contraction becomes established in a continuous circular ring of muscle Having once activated the fibers of this ring of muscle, the process does not end and await the genesis of another impulse The same impulse re enters the muscle it has already traversed, thus producing a continuous progressive contraction of one segment of the fibers of the ring of muscle after another This may continue indefinitely provided the muscle immediately in front of the forward moving crest of the wave has recovered from its refractory state Failure of this recovery will end the circus movement the quinidine treatment of auricular flutter and auricular fibrillation is based on the *fact that this drug prolongs the refractory state and thus ends the* movement [26]

There is reason to believe that the rings of muscle in which a circus movement becomes established are around the mouths of the venae cavae

* Most of the data relating to the circus movement in auricular flutter and fibrillation has been taken from the work of Lewis [9]

Electrical changes in this small ring of muscle which Lewis[27] has called the mother circus could hardly be expected to account for all the changes seen in the electrocardiogram According to Lewis conception what takes place in the mother circus is transmitted by a centrifugal like action to the rest of the auricular muscle it is the electrical changes developed in the latter that produces the characteristic electrocardiographic changes of auricular flutter and fibrillation

In both conditions the chief feature upon which the electrocardiographic diagnosis is based is a series of waves each produced by the complete involvement of the muscle of the mother circus and the resulting activation of whole masses of auricular muscle These auricular waves are really continuous oscillations since there is no isoelectric period between each deflection The shadow of the galvanometer string is constantly in motion This is necessarily so since by the very nature of the circus movement the muscle of the auricle is never either entirely active or entirely inactive—some portions are active while others are at rest.

While both flutter and fibrillation depend upon the same mechanism there are differences which make the two conditions distinct The chief factor that produces these differences is the state of the refractoriness of the auricular muscle In flutter the muscle is in a much more completely recovered state with the result that the wave moves smoothly rapidly regularly and can from cycle to cycle repeat the same course This produces auricular waves that are very regular in time and shape In auricular fibrillation in contrast the muscle of the circus and the auricle itself is in a state of partial refractoriness with the result that the contraction wave moves more slowly and with difficulty and cannot always follow the same course or complete its circuit consistently in the same time interval As a result the waves are irregular in time and not identical in shape

Another fundamental difference is the fact that the controlling ring of muscle or mother circus is longer in flutter than fibrillation Therefore in spite of the fact that the impulse travels quickly the long circus makes the time required for its complete traversal longer In flutter therefore the rate of the regular oscillations is slower than the somewhat irregular oscillations of fibrillation

(b) **Auricular Flutter**: Auricular flutter is not nearly as common as auricular fibrillation. In our hospital practice, we have encountered it in approximately one out of every 200 patients. It generally develops in patients with diseased hearts. Occasionally it is encountered in individuals without apparent cardiac abnormality.

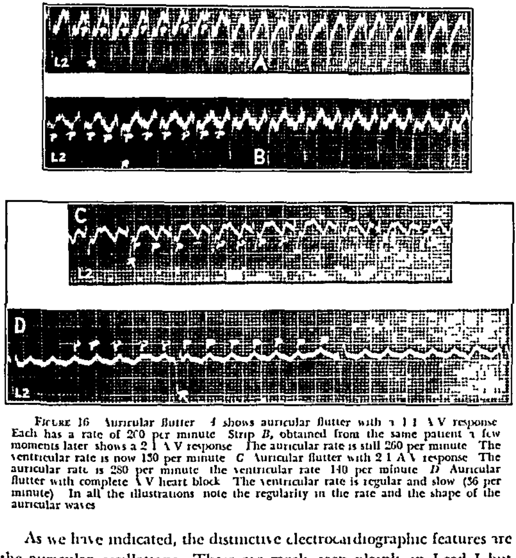


FIGURE 16. Auricular flutter. *A* shows auricular flutter with a 1:1 A-V response. Each has a rate of 260 per minute. Strip *B*, obtained from the same patient a few moments later, shows a 2:1 A-V response. The auricular rate is still 260 per minute. The ventricular rate is now 130 per minute. *C*. Auricular flutter with 2:1 A-V response. The auricular rate is 280 per minute, the ventricular rate 140 per minute. *D*. Auricular flutter with complete A-V heart block. The ventricular rate is regular and slow (56 per minute). In all the illustrations note the regularity in the rate and the shape of the auricular waves.

As we have indicated, the distinctive electrocardiographic features are the auricular oscillations. These are rarely seen plainly in Lead I but are very distinct in Leads II and III. While every oscillation is identically alike in any given lead, the shape of the oscillations vary greatly from patient to patient just as P waves do. In diagnosing flutter, it is essential that these characteristic oscillations be identified and that they be shown

to be entirely regular and at a rate between 220 and 370 per minute These auricular oscillations are quite evident with slow ventricular rates—they are not always easily recognized with the usual rapid ventricular rates for the rapidly recurring Q R S and T complexes may considerably mask the small auricular waves It is necessary to visualize what the tracing would be like if the Q R S complexes were absent As a rule this is not difficult to do flutter will rarely be missed electrocardiographically if it is thought of (Fig 16)

The ventricular response to the auricular impulses is of some importance The AV node can rarely transmit all of them to the ventricle As a rule the refractory period of the A V node allows it to transmit only every second auricular impulse At times even fewer auricular impulses pass the AV node giving an AV ratio of 3 1 4 1 or even high ratios This is usually the result either of some disease of the A V node or the action of digitalis Under the latter circumstance the AV ratio sometimes varies from cycle to cycle The latter introduces no difficulty in the electrocardiographic recognition of flutter it may make considerable difference in a clinical diagnosis

Occasionally as a transient event the refractory period of the AV node becomes so shortened that it transmits every auricular impulse Under these circumstances the ventricle beats very rapidly we have seen it reach a rate of 260 per minute several times (Fig 16 *A*) In older individuals whose hearts are not too good unconsciousness or Stokes-Adams syndrome may result from such rapid rates

1 *Effects of Carotid Sinus Pressure* The usual effect of carotid sinus pressure in auricular flutter is to produce a temporary A V heart block lasting a few cycles the auricular rate is usually unaffected Such periods of AV block are produced more easily when this structure has been rendered more sensitive to stimulation by the administration of digitalis to the patient

In two cases we have been able to record the change of auricular flutter to auricular fibrillation following carotid sinus pressure [8]

2 *Types of Auricular Flutter* Auricular flutter may occur in a paroxysmal form or as an established flutter The latter form is said to be present if its duration has been two weeks or more Instances have been recorded where the flutter lasted uninterruptedly for eight years

3 *Effects of Drugs in Auricular Flutter* Digitalis which is the drug of choice in the treatment of auricular flutter usually first produces an increase in the grade of A V block then converts the flutter to auricular fibrillation If digitalis is then stopped the auricular fibrillation frequently reverts spontaneously to normal rhythm If this does not occur the fibrillation may tend to persist unless quinidine is given to establish normal rhythm

Quinidine sulfate if effectual converts the flutter to normal rhythm without an intervening stage of auricular fibrillation it often slows the auricular rate considerably during auricular flutter This may fall as low as 130 per minute

Beta methyl choline has been successfully used to change auricular flutter to auricular fibrillation by reason of its vagal stimulating effect [32]

(c) Auricular Fibrillation *Because of the differences which we have* already pointed out the auricular oscillations in auricular fibrillation are much more rapid than they are in flutter (400 to 700 per minute) and are irregular in time and shape These characteristics of the auricular oscillations may help in the electrocardiographic recognition (Fig 17) However the auricular oscillations are rarely as prominent as they are in flutter They may be present only in one lead or possibly only in an occasional cycle Sometimes the oscillations are not visible in any indirect lead usually they can be shown by appropriately placed chest leads When the oscillations cannot be made use of because of their absence the diagnosis must be established by other criteria The absence of a definite consistent P wave before each Q R S complex may help But even this may be difficult to be certain of The one consistent electrocardiographic finding is the one that is so prominent clinically complete irregularity of the ventricular response to the very rapid auricular stimuli There are instances in which the slightly irregular ventricular rhythm *is not sufficiently marked to be detectable by the ear but one usually has* no difficulty in detecting the complete irregularity in the tracing Very occasionally the ventricles may be regular This is usually seen where digitalis has caused complete or nearly A V heart block

The application of these criteria either alone or combined usually makes the electrocardiographic diagnosis quite easy

There are some instances in which the auricular waves are large only slightly irregular and of a rate more like that of flutter than fibrillation

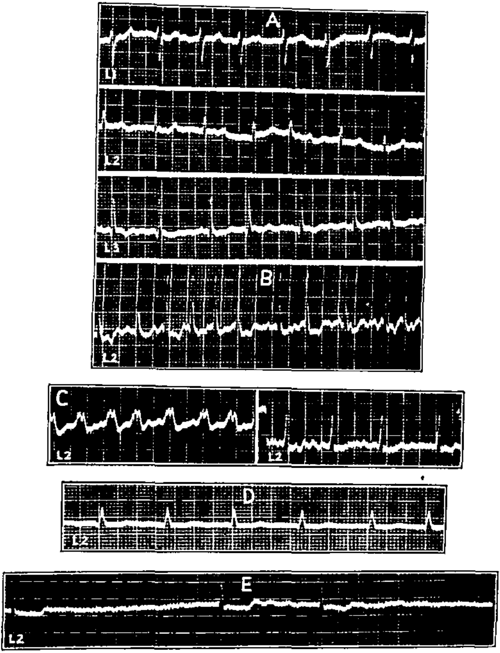


FIGURE 17 Auricular fibrillation *A* is from a case of mitral stenosis There is a right axis deviation The ventricular rate is fairly well controlled by digitalis Note the absence of P waves and their replacement by small irregular oscillations which are called f waves Note also the total irregularity in the spacing of the R R interval *B*, Auricular fibrillation with a rapid ventricular rate averaging 170 per minute *C*, The first strip shows auricular fibrillation with a rapid ventricular rate (approximately 170 per minute) Note the widening and notching of the Q R S complexes indicating a high grade of bundle branch block The second strip, obtained from the same patient, after the ventricular rate had been well controlled by digitalis shows normal intraventricular conduction thus indicating that the bundle branch block observed in the first strip was due to fatigue of the tissues of the bundle branches incident to the high ventricular rate *D*, The ventricular rate is almost regular Such cases are difficult to diagnose clinically Note the almost complete absence of auricular f waves *E*, There is a high grade A V heart block, due to digitalis.

frequently associated with rheumatic heart disease although it is almost as frequently encountered in hypertensive and arteriosclerotic varieties Hyperthyroidism not infrequently precipitates this irregularity often it is of the paroxysmal variety Luetic heart disease is rare as an etiologic factor

J INTRAAURICULAR BLOCK

Intraauricular block is characterized by absence of the auricular beating (P waves) for several cycles or for even longer periods It has been reported as occurring in quinidine intoxication 60 This condition must be differentiated from nodal rhythm where the P waves may be buried in the Q R-S complexes by a jugular pulse tracing and from the extremely low isoelectric P waves by the same method and by use of precordial leads

K AURICULAR STANDSTILL

Auricular standstill may be caused by toxic quinidine effects by carotid sinus pressure and by reflex vagal stimulating effects from the gastrointestinal tract In these conditions the ventricle ultimately escapes Total cardiac standstill may be present for varying periods of time up to 30 seconds during Adams-Stokes seizures

L AURICULOVENTRICULAR HEART BLOCK

This term is applied to the abnormal cardiac mechanism in which an auricular impulse is delayed or completely fails to reach the ventricle This disturbance is the result of disease or abnormal function of the A V node or bundle of His In its simplest form every auricular impulse reaches the ventricle but requires a longer time interval With higher grades of block occasional auricular impulses fail entirely to secure ventricular responses The auricular and ventricular responses may assume a regular mathematical ratio such as 2 3 or 4 auricular impulses to 1 2 or 3 ventricular responses With complete A V block no auricular impulses reach the ventricle Complete and partial A V block have the following electrocardiographic difference In partial A V block every ventricular beat present is a response to a preceding auricular impulse in complete A V heart block no ventricular beat is a response to auricular impulses but is a response to impulses originating within the ventricle

Both complete and partial block generally occur in older individuals and are usually the result of actual degenerative changes in the A V node However both types may depend on reversible changes that do not pro-

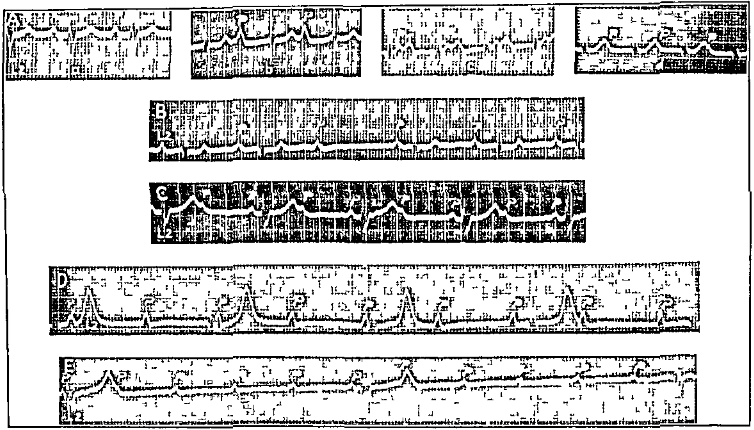


FIGURE 18. A-V heart block. A shows various types or grades of P-R interval prolongation. (*a*) Shows P-R intervals of 0.20 second. (*b*) shows P-R intervals of 0.40 second. (*c*) the P waves are situated between the Q R S complexes and the T waves; the P-R interval measures 0.44 second. (*d*) the P wave is very small and superimposed on the T wave. *B* shows a partial A-V heart block with prolonged P-R intervals measuring 0.40 second. In the second cycle there is seen a dropped ventricular beat: an auricular wave with no ventricular response. Note that the P-R interval preceding the next ventricular cycle is shorter than the others. The A-V node conducts more efficiently as a result of the longer rest period. *C* shows partial A-V heart block with 2:1 A-V response (2:1 A-V heart block). The auricular rate is 100 per minute and the ventricular rate 50 per minute. Note that the P-R interval preceding each Q R S complex is exactly the same length. *D* shows complete A-V heart block. The ventricular rate is 30 per minute. The ventricular response is quite regular. The auricular rate is 68 per minute and the rhythm regular. The ventricular and the auricular rhythms are entirely independent of each other. No R waves are responses to preceding P waves; hence the P-R intervals are not related and these intervals vary in length. *E* (from the same patient). The auricular rate is 88 per minute but the ventricular rate is only 16 per minute.

duce visible pathologic lesions and can be transient phenomena. This is particularly true of partial block which is produced transiently by such conditions as rheumatic fever, asphyxial conditions, by digitalis and vagal overactivity. Both partial and complete A-V block are also seen transiently as a complication of occlusion of the right coronary artery. *Syphilis is very rarely an etiologic factor in A-V heart block.*

(a) Partial A-V Block: (Fig. 18 *A*, *B*, and *C*): When there is only delayed A-V conduction, it is practically impossible to recognize this clinically. The only possible clues lie in the facts that the first heart sound may be diminished in intensity and at favorable rates, a summation gallop may be detected by auscultation.[30] However, this condition is recognized easily by the electrocardiogram which clearly shows long P-R intervals. This interval normally should not exceed 0.2 second.

When partial block produces dropped beats, clinical recognition is generally possible. However a 2:1 A-V block may be mistaken for a slow sinus bradycardia and the pause produced by a dropped beat may be confused with the compensatory pause of a ventricular extrasystole. The electrocardiograph plainly reveals this condition by showing regularly recurring, normally shaped P waves with an occasional one failing to be followed by a ventricular response (Fig. 18 *B*).

(b) Complete A-V Block: Although instances are known in which complete block has existed for 20 years or more, these are rare and the condition is to be regarded as a serious disturbance in which the prognosis is definitely poor. This is so because the disturbance predisposes to ventricular standstill or ventricular fibrillation, both of which may quickly cause death. These will be discussed under Stokes-Adams seizures.

The diagnosis usually can be made clinically by the slow and regular ventricular rate which is a result of the initiation of impulses by an idioventricular center at a rate usually around 40 per minute. The new idioventricular center is below the point of block and probably in the A-V node or bundle of His. The chief therapeutic attack is directed toward preventing this idioventricular center from failing or toward increasing its rate of impulse formation. Neither can be very well accomplished, but atropine, adrenalin, ephedrine, paredrine and typhoid vaccine,[74] may at times accomplish the latter aim.

The electrocardiographic diagnosis is easily made The ventricular complexes occur regularly and slowly While the ventricular rate is usually slow 30 to 40 per minute this may be higher (60 per minute) in complete heart block due to digitalis and in emergence from Stokes Adams seizures *where it may be 100 per minute* The auricular complexes are entirely independent and usually occur regularly at a normal rate (Fig 18 *D* and *E*) It is to be borne in mind that there is no reason why complete A V block cannot exist in the presence of an abnormal auricular mechanism One therefore sees complete A V block occasionally when the auricles are fibrillating or fluttering or beating very rapidly[31]

The ventricular complexes are generally normal in duration and in contour At times they are widened and notched because of coexistent bundle branch block

M AURICULOVENTRICULAR NODAL RHYTHM (*Fig* 19)

According to the conception that is generally held all heart muscle possesses certain fundamental properties among which are excitability and rhythmicity In the sinoauricular node the property of rhythmicity is more highly developed than in any other portion of the heart muscle hence it is the pacemaker of the heart However the A V node possesses the property of rhythmicity in only slightly less degree and readily takes up the role of pacemaker if either of the following two developments takes place (1) The rhythmicity of the S A node becomes depressed to a level lower than that inherent in the A V node or (2) the rhythmicity of the A V node becomes heightened to a point above that of the S A node Since the natural rate of the rhythmicity of the A V node is around 40 to 50 per minute the former development (1) results in a slow heart rate and may be called the slow type of nodal rhythm while the latter (2) produces a rate more rapid than the usual sinus rate and can be referred to as the rapid type of nodal rhythm

Neither type is very common but the slow form is seen much more often than the rapid Both forms of A V nodal rhythm are nearly always temporary disturbances only a few instances have been reported where the disturbance approached permanency Among the causes are digitalis poisoning acute rheumatic fever arteriosclerosis of the coronary arteries with resulting degenerative changes in the sinoauricular node In certain patients it occurs during certain phases of respiration after carotid sinus pressure and atropine administration

The term A-V nodal rhythm is usually applied when the impulses arising in the A-V node, either slowly or rapidly, spread both downward to the ventricles and upward to the auricles as well, and thus control both chambers. This is not always the case, however, for frequently the nodal impulses go only to the ventricles, the auricles remaining under control of the sinoauricular node. When this is the case, some other name (ventricular escape) is given to the disturbance.

In considering the electrocardiographic diagnosis of A-V nodal rhythm, it should be pointed out that the A-V node is a relatively long structure—so much so that the electrocardiographic findings differ depending upon whether the impulses arise in the head or auricular end, in the tail or ventricular end or in the center. What usually is seen is a migration of the center of impulse formation with some impulses arising from one situation in the node and some from another. Regardless of which center is active, there is one common feature: The auricular P waves are inverted or at least different in shape from P waves originating in the sinus node. This is so because an impulse arising in the A-V node follows an entirely different course through the auricular muscle than one arising in the sinus node. The Q-R-S complexes are usually supraventricular, that is to say of normal width and shape, though occasionally one sees a slight aberration in the shape of this complex.

When an impulse arises in the ventricular end of the node, it has a much shorter distance to go to reach the ventricle than the auricles. As a consequence the ventricles are activated and contract before the auricles, with the result that the inverted P waves are usually situated between the Q R S complex and the T wave (Fig. 19 *C*).

When an impulse arises in the auricular end of the node, the distance to be traversed to reach the auricles is short and the auricles beat before the ventricles However, as the impulse is spreading from its point of origin upward towards the auricles, it is also spreading towards the ventricle with the result that when the impulse reaches the auricle and the P wave begins to be written, the impulse will by then be well on its way through the node toward the ventricles. This naturally results in the P R intervals being quite short (Fig 19 *A*).

With slow nodal rhythm, this variety with short P-R intervals can be recognized unmistakably With rapid nodal rhythm, it may be confused with auricular paroxysmal tachycardia The distinguishing point

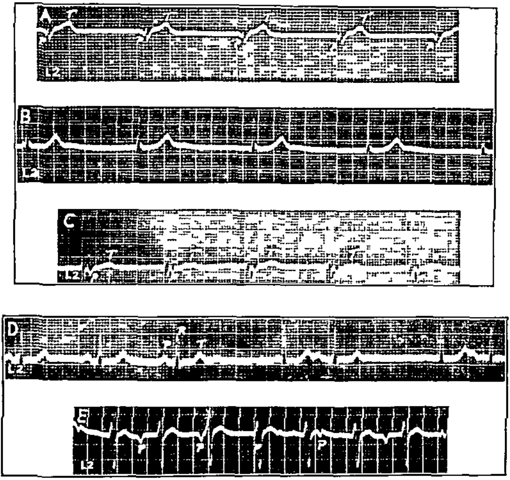


FIGURE 19 Auriculoventricular nodal rhythm and ventricular escape *A*, *B* and *C* show different examples of the slow form of nodal rhythm *A* The ventricular rate is 50 per minute Note the extremely short P R intervals (0 06 second) and the inverted P waves The center of impulse formation is in the upper portion of the A V node *B* The ventricular rate is 43 per minute The P waves occur synchronously with the Q R S complexes and therefore are not visible The impulse probably arises from the middle portion of the A V node and spreads simultaneously to the auricles and the ventricles *C*, The ventricular rate is 50 per minute The P waves are inverted and occur between the Q R S complexes and the T waves The impulse arises from the lower portion of the A V node and reaches the ventricles slightly before the auricles *D* and *E* *illustrate two forms of ventricular escape In D the first three cycles are normal The* interval between the third and the fourth P waves is exactly twice the usual P P interval (sinoauricular heart block) As a result of the much delayed auricular impulse the A V node escapes and initiates an impulse which goes forward to the ventricles (fourth and sixth ventricular complexes) but not to the auricles the latter remaining under the control of the sinoauricular node Two instances of such ventricular escape are observed in this record In *E* the P waves occur regularly and at a normal rate The ventricles are beating independently of and more rapidly than the auricles This type of A V dissociation develops when some influence raises the rate of rhythmicity of the A V node above that of the sinoauricular node The rapidly formed A V nodal impulse in this instance goes forward to the ventricles but not backward to the auricles The P waves are therefore seen to occur regularly but have no relation to the following ventricular complexes

is the short P R interval of nodal rhythm this interval will not be materially shortened in extrasystolic disturbances

When the impulse arises around the center of the node it may reach the auricles and ventricles simultaneously with the result that the Q R S and P waves occur simultaneously and the latter are invisible When this is the case the diagnosis is sometimes uncertain and must be arrived at largely through elimination If one takes enough tracing usually a cycle or cycles will be found in which the P wave shows for as we have already stated the center of impulse formation in the A V node generally moves and rarely remains fixed (Fig 19 *B*)

(a) A V Nodal Extrasystoles and Nodal Paroxysmal Tachycardia A nodal extrasystole is simply a single cycle of rapid type nodal rhythm That is to say for one cycle the rhythmicity of the A V node is raised to a higher level than that of the S A node The electrocardiographic features are those that we have already described The P waves will be inverted and will be either before behind or buried in the Q R S complexes If before the Q R S complexes the P R interval will be shortened

If instead of a single isolated nodal extrasystole there occur a series of these beats this constitutes nodal paroxysmal tachycardia As the name implies it is paroxysmal and the rate may rise as high as 140 to 160 per minute This disturbance is the typical example of the rapid type of nodal rhythm but is quite rare

(b) Ventricular Escape We are using this term to apply to those instances in which impulses arising in the A V node go forward and control the ventricle but do not reach the auricles the latter remaining under control of the sinoauricular node The factors that produce this disturbance and the forms in which it manifests itself (slow and rapid) are those already discussed There is that type in which the rate of rhythmicity of the sinus node becomes depressed to the point that the normal stimulation of ventricular contraction by the auricular impulse is so delayed that the inherent rhythmicity of the A V node asserts itself and produces a stimulus This is precisely the mechanism at work in the slow type of nodal rhythm except that the nodal impulse in ventricular escape effects only the ventricles and not the auricles This slow type of escape is often confined to a single cycle frequently an exaggerated sinus arrhythmia will bring it into play It may be present however for a number of cycles

This can be easily recognized in the electrocardiogram by the fact that the escape ventricular complexes are not preceded by P waves The latter can usually be seen at least partially behind the Q R S complexes and can be seen to be normally upright and therefore of sinus origin (Fig 19 *D*)

The mechanism of the other variety of ventricular escape is that of rapid nodal rhythm the rate of rhythmicity of the A V node is raised above that of the sinus node If the nodal impulses thus resulting can go forward but cannot go backward through the node the ventricles are controlled by these impulses but the auricles continue to beat in response to sinus impulses We have therefore an A V dissociation with the ventricles beating more rapidly than the auricles (Fig 19 *E*)

In the electrocardiogram this is plainly seen The ventricular beats are of normal shape but are not preceded by P waves at a consistent P R interval The ventricular complexes are regular in rhythm and are all responses to nodal impulses except that an occasional beat may be out of rhythm because it is a response to an auricular and not a nodal impulse This can happen when the auricular impulse finds the refractory state of the A V node and ventricles favorable The P waves are normally upright regular and occur at a slower rate than the ventricular complexes

N VENTRICULAR EXTRASYSTOLES

There is considerable evidence to suggest that the mechanism of ventricular extrasystoles is not a simple one Since the matter is not entirely clear we will refer only to the older view and not discuss the parasystolic theory of extrasystoles (see Fig 14 *A* *B* and *C*) Ventricular extrasystoles are generally considered to be the result of a stimulus to contraction arising at some place in the ventricular muscle Ventricular beats produced by this mechanism are always premature and since the impulse arises in the muscle of one ventricle this chamber will be activated before its fellow with the result that the two ventricles act asynchronously This produces ventricular complexes which are slurred widened and of considerable voltage The T waves are also large and opposite to the direction of the Q R S complexes Widening and notching of the premature ventricular complexes is not sufficient for diagnosis it must be further shown that these complexes are not preceded by P waves It is upon these features that the electrocardiographic diagnosis is made

Ventricular premature contractions may appear in the form of isolated beats; they may be numerous, arise from one or many foci, or occur in pairs or short runs of three or more beats, thereby constituting a potential ventricular tachycardia. A very interesting variety is that in which ventricular extrasystoles are coupled to preceding normal complexes in the sense that the time interval between the extrasystole and the preceding normal complex is the same from cycle to cycle (Fig. 14 *B*). The chief clinical importance of this disturbance lies in the fact that it is frequently produced by overdigitalization. Theoretically they are of interest because they suggest the possibility that the mechanism back of extrasystoles may be a form of the re entrance phenomenon and may, therefore, be close to the circus movement that produces auricular fibrillation and flutter.

Ventricular extrasystoles occurring late in diastole give rise to an effective ventricular contraction which produces a radial pulse. Occurring early in diastole, the intraventricular pressure may be too small, as a result of insufficient ventricular filling, to yield a pulse at the wrist. A pulsus deficit may therefore occur in the presence of numerous ventricular premature beats

The auricular mechanism is not disturbed by ventricular extrasystoles: P waves continue to be formed rhythmically. This gives rise to one of the outstanding clinical phenomenon; the compensatory pause. The P wave that occurs during or just after the premature ventricular beat cannot secure a ventricular response for it occurs during the refractory period of the ventricle The first ventricular contraction after the premature beat will be a response to the next rhythmic P wave. The interval between the premature beat and the next ventricular beat is therefore longer than the usual R-R interval and is referred to as the compensatory pause

However, if the premature beat occurs sufficiently early in diastole at a relatively slow ventricular rate (*e.g.*, 60 per minute), ventricular recovery may have proceeded to such an extent that every rhythmic P wave secures a normal ventricular response and no compensatory pause occurs. Such extrasystoles are referred to as interpolated.

Ventricular extrasystoles may arise in the right ventricle, the left ventricle or the interventricular septum. The point of origin may be determined by the direction of the extrasystoles in Leads I and III. If

upright in Lead I and down in Lead III, they are probably right ventricular, if down in Lead I and upright in Lead III, they are of left ventricular origin[20]

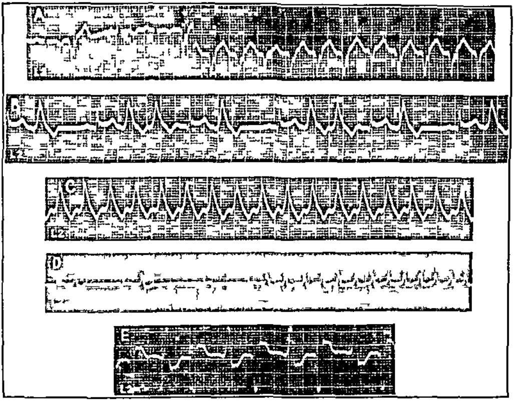


FIGURE 20 *Ventricular paroxysmal tachycardia* *The first portion of strip A shows* periods of normal rhythm interrupted by an occasional ventricular extrasystole In the rest of the strip there is a paroxysm of ventricular tachycardia (ventricular rate 154 per minute) Note that the ectopic beats of the paroxysm are identical in shape with that of the isolated ventricular extrasystoles Normally shaped P waves continue to occur regularly at a much slower rate (115 per minute) and independently of the ventricular complexes *B* and *C* are from the same case of ventricular tachycardia occurring during acute pericarditis In *B* are shown isolated ventricular extrasystoles some of which are occurring in pairs *C* shows a continuous ventricular tachycardia Note that the ectopic beats are identical in shape with the isolated ventricular extrasystoles observed during the normal rhythm The ventricular rate during the paroxysm is 160 per minute *D* Ventricular paroxysmal tachycardia occurring during auricular fibrillation Note the normal ventricular complexes followed by coupled ventricular extrasystoles During the paroxysms the shape of the ventricular complexes is the same as that of the isolated extrasystoles Note also that the initial beat of the paroxysm bears the same relation to the preceding normal beat that the isolated coupled beats bear to the preceding normal beat *E* shows ventricular paroxysmal tachycardia of the bidirectional type occurring in a patient during toxic digitalis effects Note the presence of R T deviations

Since this disturbance is a very common one its clinical significance is important *Undoubtedly ventricular extrasystoles occur as the result* of myocardial diseases of various types But they also occur frequently in individuals with normal hearts Their importance, therefore, is to be

evaluated by clinical study alone they warrant no diagnosis of disease In most instances they can be abolished by any factor that increases the cardiac rate *e g*, emotion exercise or atropine In some cases where they occur *in association with myocardial disease* exercise tends to increase them by putting a greater load on an already overburdened heart muscle

O VENTRICULAR PAROXYSMAL TACHYCARDIA (Fig 20)

Ventricular paroxysmal tachycardia generally is considered to be a disturbance consisting of a series of ventricular extrasystoles The ventricular rate is usually around 150 to 170 per minute The diagnosis can be made with certainty only by electrocardiographic study The criteria for electrocardiographic diagnosis of ventricular tachycardia were *established by Robinson and Herrmann*[33] *The beats of the paroxysms* should be ventricular in type in the sense that they are widened and notched If auricular fibrillation exists it is essential for the diagnosis that tracings be obtained when the ventricular paroxysm is not present and which show isolated ventricular extrasystoles—preferably those which are coupled to preceding normal beats (Fig 20 *D*) The diagnosis can be established if the ventricular complexes of the paroxysm are identical with the isolated ventricular extrasystoles It is even more fully established if the first beat of the paroxysm is coupled to the preceding normal complex by the same time interval that exists between an isolated extrasystole and its preceding normal beat If auricular fibrillation is not present the diagnosis is established if the ventricular complexes are widened and notched and occur more rapidly than and independent of the normally shaped P wave The ventricular rate may be perfectly regular but generally is slightly irregular It has been suggested that this slight irregularity together with the variation in the intensity of the first sound which is often present may suggest this arrhythmia clinically[34]

This arrhythmia is of great prognostic significance since its duration for any period of time predisposes to ventricular fibrillation a condition usually incompatible with life It occurs in the presence of severe myo*cardial disease* particularly as a complication of acute or subacute coronary occlusion and as the result of toxic digitalis effects

The complexes of ventricular tachycardia are usually unidirectional Occasionally they are bidirectional (Fig 20 *E*) this is probably a more

serious type and is in our experience, almost always a result of toxic digitalis action From theoretical considerations, this type has been said to be due to a circus movement in the ventricle and has been called ventricular flutter analogous in mechanism to auricular flutter [67]

Two other types of ventricular tachycardia are sometimes observed *When present, they usually produce Stokes Adams seizures* The first producing minor attacks, consists of markedly aberrant widened Q R S complexes (Fig 21 *A*), they differ from the usual type observed in ven

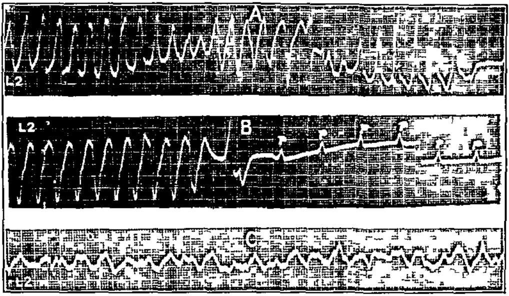


FIGURE 21 Ventricular fibrillation Strips *A* *B* and *C* were obtained during a Stokes Adams attack in a patient with complete A V heart block Strip *A* shows the prefibrillary type of ventricular tachycardia Note the markedly aberrant type of ventricular complexes with a rate of 200 per minute These very frequently precede the development of ventricular fibrillation or complete ventricular standstill *B* shows the typical prefibrillary type of ventricular tachycardia (rate 200 per minute) This ends suddenly and is followed by a period of ventricular standstill During the ventricular disturbance the auricles continued to beat at a rate of 88 per minute *C* shows ventricular fibrillation Note the extremely irregular aberrant type of ventricular response The patient recovered from this paroxysm

tricular tachycardia in that the rate is more rapid (200 to 230 per minute) and the amplitude of the Q R S greater (Fig 21 *A*) The second type produces major seizures The complexes show greater widening and are *more bizarre The waves consists of more or less regular helixlike undu*lations which usually precedes true ventricular fibrillation (Fig 21 *B*) Both of these variations have been referred to as prefibrillatory types of ventricular tachycardia

P. VENTRICULAR FIBRILLATION

Ventricular fibrillation (Fig. 21 *C*) is the most serious of the arrhythmias; its presence for even a brief instant is usually incompatible with life, though there are on record a few instances in which recovery has occurred after ventricular fibrillation had existed for several minutes. This arrhythmia is probably a frequent terminal event in many patients. It is probably the mechanism by which death occurs in coronary occlusion, digitalis poisoning and in some Stokes-Adams attacks. It is usually preceded by attacks of ventricular tachycardia.

The cardiac mechanism during these seizures may be more easily followed in animals where they can be induced by electric shock, by coronary occlusion or by toxic amounts of digitalis With the onset of ventricular fibrillation, the blood pressure drops to zero or practically so; a series of rapid irregular undulations replace the coordinated contraction of the ventricle. These oscillations become gradually less marked until they cease altogether.

The graphic records show bizarre ventricular oscillations without suggestion of a Q R-S or T wave. The waves are often very coarse and irregular and are accompanied by wide movement of the string. Auricular contractions may nevertheless be present. Records of onsets during Stokes-Adams seizures in complete A-V block show that this arrhythmia is usually preceded by ventricular tachycardia, especially of the prefibrillatory type and may begin suddenly following a period of ventricular standstill.[35] Recorded endings have shown the gradual appearance of ventricular beats, at first markedly aberrant, later less so. The idioventricular beats gradually resume their usual contour and rate.

In animals, such seizures induced by electric shock have been terminated and normal rhythm restored by application of potassium followed by calcium salts and by electric countershock.[71] So far, few such attempts to accomplish this in the human subject have been made.

Q. PULSUS ALTERNANS

Pulsus alternans is characterized by rhythmic occurrence of a strong, followed by a weak beat The resulting pulse waves alternate in strength. The ventricular rate is quite regular. The pulse rate, however, may be slightly irregular due to a variation in sphygmic intervals as a result of variation in ventricular ejection. Alternation may involve the auricle, both ventricles, or only the right or left ventricle; it has been observed

even in the presence of auricular fibrillation. This condition may be detected at times by palpation of the radial pulse. It is, however, more accurately determined by the use of the blood pressure cuff which may indicate variations in the systolic pressure in alternate cycles of from 12 to 30 mm., or by graphic registration of the brachial or radial pulse. Occasionally, alternation of the heart sounds may be recorded at the apex. One must be careful to exclude the presence of coupled rhythm; in this condition the apical rate is irregular.

Alternation is generally the result of a profound cardiac disturbance. However, when it is present only with very rapid rates, it is not nearly so significant. It is not uncommon during rapid paroxysmal tachycardia; the alternation disappears as the rate is slowed.

There are two main theories underlying alternation: (1) That all the fibers contract during one cardiac cycle, but due to diminished excitability some fibers do not contract in the next cycle,[36] and (2) that separate groups of fibers fail with alternate beats.[37]

Evidence of alternation may be present in the electrocardiogram (electrical alternation). This may occur together with or be independent of mechanical alternation; its significance, however, is the same. The electrocardiogram may indicate alternation in the height of the Q R S complexes (Fig. 15), alternation in the length of the P R interval, and alternation *in the amplitude of the T waves in indirect and/or precordial* leads.[35]

VII. CORONARY OCCLUSION

Since Herrick[38] placed the diagnosis of coronary artery occlusion on a firm clinical basis, a number of gradually accumulating observations have given to the electrocardiogram a prominent place in the study of this important condition. Among these, the experimental work of F. M. Smith[39] and that of Pardee,[40] Parkinson and Bedford,[41] and Barnes and Whitten[42] deserve special mention. Since 1932, the diagnostic possibilities of the electrocardiogram have been markedly increased by the use of the precordial leads, the value and importance of which has been clearly shown by the work of Wolferth and Wood[2] and that of Wilson.[3] By the combined use of the limb and precordial leads, the diagnosis of myocardial infarction can now be made by the electrocardiogram in over 90 per cent of cases. In addition, the site of the infarcted

area can be usually definitely determined and the course of healing can be followed by the careful use of the electrocardiograph.

Determination of the site of infarction is important in prognosis. Cases of posterior infarction present a better outlook than anterior myocardial infarction and usually require a relatively shorter period of bed rest.

A. PHYSIOPATHOLOGIC CONSIDERATIONS

Before discussing the electrocardiographic changes in coronary occlusion, certain physiopathologic facts should be pointed out.

Coronary occlusion is most apt to occur in either one of two sites—in *the anterior descending branch of the left coronary artery, 1 to 1.5 cm.* from its orifice, or in the right coronary artery. Closure of right coronary artery occurs near its orifice but more often near the crus where the right circumflex turns to become the posterior descending branch of the right coronary artery.

Immediately following the occlusion, the normal electrical excitation is disturbed in the damaged muscle and is replaced by abnormal currents which occur in injured muscle. These are called currents of injury and produce the characteristic change in the electrocardiogram, namely deviation of the R-S T segments and T wave changes. At varying periods following the occlusion, irreversible changes appear in the heart muscle; myocardial infarction takes place and reaches its maximum extent 24 to 48 hours after the acute occlusion or even later, depending on the type and character of the occlusion. This is followed by a period, if the patient survives, during which the process of infarction merges into a subacute phase where many of the acute features subside. It is difficult to give accurately the length of the acute and subacute stage in human cases, however, judging from the sequence of events in dogs and relating these to serial electrocardiograms and post mortem findings in humans, *it appears that in the average case, the acute and subacute stages have an average of two to three weeks duration in posterior and three to five weeks in anterior infarctions.* This varies greatly in different cases. At necropsy, one often observes healing in one portion and evidence of acute and subacute infarction in another portion of the involved area.

Strictly speaking, the electrocardiographic changes are not the result of coronary occlusion The electrocardiogram records evidence of acute muscle damage resulting from the occlusion. While currents of injury

are usually the result of myocardial infarction they may be produced by other cases *e g*, inflammatory involvement of the myocardium in pericarditis acute rheumatic myocarditis and anoxia However, certain other characteristics in the electrocardiographic pattern usually enables one to decide if the currents of injury are the result of myocardial infarction or are produced by some other cause

The electrocardiographic alterations depend not only upon the location but upon the size of the infarcted area The size of the region infarcted depends upon many factors

1 The size of the vessel occluded Since considerable variation exists *anatomically in the size and distribution of various branches of* the coronary arteries occlusion of the same vessel in different hearts does not necessarily give rise to areas of infarction similar in extent To *mention but a few examples of such variations* (*a*) The right coronary artery is occasionally a much smaller vessel than usually observed under which circumstance a portion of the area supplied by this artery is taken by the circumflex branch of the left coronary (*b*) The upper lateral wall of the left ventricle generally supplied by the circumflex branch of the left coronary artery is in ten per cent of hearts replaced by a large circumflex branch of the right coronary artery (*c*) Considerable variation exists in size and number of the lateral branches of the anterior descending branch of the left coronary artery and their manner of branching

2 The mode of formation and size of the thrombus Closure may develop slowly permitting opportunity for neighboring vessels to supply the infarcted area The thrombus may be small (½ to 1 cm) thus allowing the occluded artery to function by its connections to neighboring vessels An initially small thrombus may gradually or rapidly extend ultimately involving the entire vessel thus depriving a considerably greater area of its blood supply

3 The thrombus may be single or it may be preceded by previous thrombi in the same vessel the vessel itself may have previously been the seat of arteriosclerotic narrowing at one or more points

4 The age of the patient is of some importance Closure of a coronary artery in a relatively young person is said to carry with it a more serious prognosis than in an older patient, due to the presence of more

anastomic channels in the latter and the inability of arteriosclerotic vessels to develop a spastic closure of their lumina.

5. The occurrence of spasm in the remaining coronary arteries following an acute occlusion[43] is an *important factor in determining the* extent of the infarcted area and ultimately the patient's survival. This spastic factor would not be as important in the presence of arteriosclerotic coronary arteries since these cannot so readily go into spasm.

6. The factor of *cardiac rest includes the rapidity with which complete* physical and mental rest is secured following the occlusion. The continuance of the patient at work, the withholding of analgesics and sedatives during periods of pain increases the work of the heart and would tend to *increase the size of the involved area and delay healing.* The same is true if a rapid ectopic rhythm develops following a coronary occlusion; this would tend to decrease the coronary flow while at the same time increasing the work of the heart.

7. The *presence of new areas of infarction gradually forming during* the process of healing of the original process may prolong the acute and subacute stages to two to three months or longer.

8. The previous status of the coronary circulation is of great impor*tance. Many patients with coronary occlusion have two or more infarc*tions at various times The occurrence, for example, of a posterior infarction after a previous anterior infarction increases the extent of the infarcted area in the former since a large portion of its possible anasto*matic supply* is cut off.

B. THE ELECTROCARDIOGRAM IN MYOCARDIAL INFARCTION

In view of the numerous variations in the type, progression and extent of myocardial infarction, it becomes apparent how markedly the electrocardiogram may vary. From the graphic standpoint, four types of coronary artery occlusion have been described, anterior, posterior, anteroposterior and lateral. Other types and combinations occur, but the electrocardiographic diagnosis of these is not clear cut. About 90 per cent of the cases of myocardial *infarction* are *represented by infarction* of anterior and posterior wall of the left ventricle; the remainder constitutes the other ten per cent.

(a) Anterior Myocardial Infarction: Occlusion of the anterior descending branch of the left coronary artery results in *infarction involving*

the anterior and apical portion of the left ventricle and the lower left contiguous portion of the interventricular septum An electrocardiographic pattern is produced which is usually fairly characteristic However, deviation from the typical patterns are frequent

1. *Acute Stage (Stage of R T Deviation)* The acute stage is characterized by the presence of R-T deviation which presents a characteristic

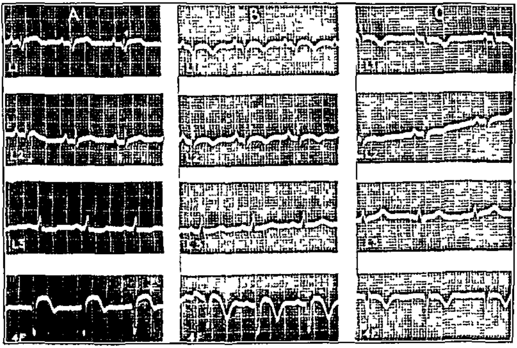


FIGURE 22 Anterior myocardial infarction *A* was taken 24 hours after the onset of severe precordial pain Note the R T elevation in Lead I, and R T depression in Lead III A small Q wave is present in Lead I, and the Q R S complexes are of low amplitude in all three leads Lead IV_F shows an absence of the R wave and elevation of the R T segment *B* was made three weeks after *A* The T waves in Leads I and II are now inverted and cove shaped Lead IV_F still shows the absence of the R wave The R T segment is now only slightly elevated but the T waves are deeply inverted and somewhat increased in amplitude *C* was taken four weeks after *B* Note the presence of a small Q wave in Lead I T_1 is still inverted, but is no longer as characteristically cove shaped *as in B* T_2 *is inverted still but not as much as in B* Lead IV_F still shows the absence of R waves The R T deviations have entirely disappeared The T waves are inverted but not as deeply as in *B*

pattern (Fig 22 *A*). This is represented by the T_1 type of R-T deviation (if a Q wave is present in Lead I, it is called the Q_1-T_1 type) With a left axis deviation the R-T segment is elevated in Lead I and depressed in Lead III, the R-T segment in Lead II depends upon the algebraic summation of T_1 and T_3 In the presence of a bicardiogram, the R T segment is elevated in Leads I and II; R-T_3 is usually unaffected

The precordial leads show an absence of the initial upward deflection in IV_F or IV_R (absence of initial downward deflection in old Lead IV) With subsidence of the acute stage the R-T deviation becomes less marked and finally disappears first in the limb leads and later in the precordial leads

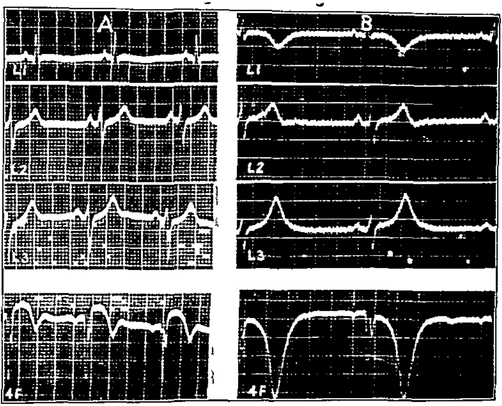


FIGURE 23 Precordial leads during the subacute stage of myocardial infarction *A* and *B* are from the same case of anterior infarction *A* was taken three days after the onset of severe precordial pain Note the slightly elevated R-T segments in Lead I with beginning inversion of the T waves The T waves *are upright in Leads II and III* A left axis deviation is present Lead IV_F shows an absence of R waves with elevated R-T segments These findings are characteristic of the acute stage of anterior myocardial infarction The changes are more plainly seen in the precordial than in the limb leads *B* was taken ten days after *A* Note the deeply inverted slightly coved T waves in Lead I the upright T waves in Lead III and the increased amplitude of T_3 In Lead IV_F the T waves are not only deeply inverted but markedly increased in amplitude The R waves are still absent These findings are characteristic of the subacute stage of anterior myocardial infarction

2 *Subacute Stage (Stage of Rapidly Changing T Waves)* With the disappearance of the R-T deviation the T wave becomes inverted in Lead I and upright in Lead III with a left axis deviation or inverted in Leads I and II if no axis deviation exists (Fig 22 *B*) These T waves often have a cove shaped configuration and the inversion is deep they

change considerably in amplitude and depth of inversion in the course of a few days or a week The T wave in IV_F is also deeply inverted and is often of considerable amplitude[44] (at times 15 to 20 mm) (Fig 23 *B* and *C*, Lead IV_F)

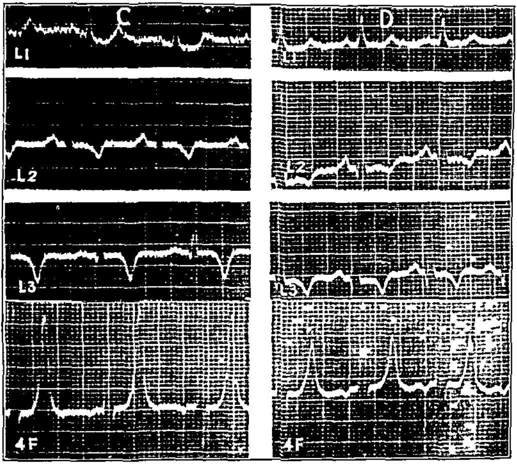


FIGURE 23 *C* and *D* are from the same case of posterior myocardial infarction *C* was obtained six days after the onset of acute precordial pain Note the typical evidence of the subacute stage of posterior infarction The S T segment is slightly depressed in Lead I and the T waves are deeply inverted in Leads II and III The inversion is quite deep in the latter lead Lead IV_F shows a maintenance of the R waves with extremely tall T waves

D was taken two weeks after *C* The S T segments in Lead I are only slightly depressed The T waves in Leads II and III while still inverted are not as deeply so as in *C* The T waves in Lead IV_F are not as tall as they were in *C* The fact that the T waves are less tall than they were in *C* suggests that the infarction is in the late subacute stage

3 *Chronic Stage (Stage of Permanent Change in Q R S T Complex)* As healing occurs, the configuration of the T waves becomes stabilized The deep coving, rapid change in shape and increased amplitude give way to a T wave of a type that may be permanent for the patient and

undergo relatively little change in the course of years. T_1 in the chronic stage is usually inverted. It may, however, become flat or even upright; T_4 mirrors closely the direction of T_1.

The initial upward deflection of the chest lead which usually disappears in the acute and subacute stage often does not return even in the healed stage; not infrequently it may return partially (2 to 4 mm.) and occasionally may be restored to its original amplitude.

4. *Variations of the Usual Pattern of Anterior Infarction: The following deviations* from the typical pattern in anterior infarction are observed:

1. The R-T changes may be absent in the limb leads and only observed in the precordial leads.

2. The electrocardiogram of the limb and precordial leads may be normal for several days after the inception of precordial pain and the changes may later appear gradually

3. The infarction may be so gradual that R-T deviations are entirely absent: Only inverted T waves in Lead I are observed in successive electro cardiograms with corresponding inversion of T_4.

4. Following upon an old posterior infarction, the limb leads may show a deep Q_3 and the amplitude of the Q-R-S may be low in all leads, including the chest lead.

5 The initial upward deflection in IV_F may be preserved in the acute stage and the only evidence of coronary occlusion are characteristic changes of the T wave in limb and precordial leads. In this pattern, the T waves are often very tall.

Cases of coronary occlusion have been observed presenting electrocardiographic patterns in which the R-T segment is elevated in Lead I and depressed in Lead III, or cove shaped inverted T waves appear in Lead I with upright T_3 associated with maintenance of the initial upward deflection in Lead IV_F throughout the acute, subacute and chronic stages of infarction. Necropsy examination in such cases has revealed the infarction to involve the anterior wall of the left ventricle away from the apex or the anterolateral wall of the left ventricle without involving the apex.

6. Another variation is that the initial upward deflection may be present in the initial tracings and disappear only gradually after a period of several days.

7. In the presence of bundle branch block either preceding or concurrent with the infarction, the pattern is often atypical (see page 674).

5 *Electrocardiographic Patterns Simulating Acute Anterior Infarction* The following conditions must be differentiated from anterior infarction

1 Small or absent initial upward deflection in the chest lead not due to anterior myocardial infarction The initial upward deflection may be extremely small (and may entirely disappear if the precordial electrode is moved upward and to the right of the apex (1 to 2 mm) in patients having severe myocardial disease involving the left ventricle (*e g* hypertension aortic insufficiency luetic heart disease with cardiac enlargement) where a marked right axis deviation is present and in the common type of bundle branch block

2 Electrocardiographic changes produced by digitalis[20] If the T waves were originally upright this drug depresses the S T interval in all three limb leads in the presence of a bicardiogram it results in a depression of ST_1 and elevation of RT_3 with a left axis deviation In the presence of previously inverted T waves and in myocardial disease the typical digitalis effects are not clearly recognized in the indirect leads However the S T deviations observed are not likely to be confused with the pattern observed in anterior infarction They simulate more closely the deviations observed in posterior infarction Confusion is most apt to result in the precordial leads where digitalis has been given to patients having a small or absent initial upward deflection not due to acute myocardial infarction With an extremely small (1 to 5 mm) or absent initial upward deflection digitalis results in an elevation of the S-T segment in Lead IV_F thus giving a picture resembling an acute anterior infarction Where the initial upward deflection is small or absent due to an old anterior infarction the digitalis R T elevation may give a picture resembling an acute anterior infarction The differential diagnosis is made by the history by the R T deviations in the limb leads (these differ in digitalis and anterior infarction) and its association with short Q T intervals (these differ in two conditions) and by the subsequent course. Serial tracings in myocardial disease present an entirely different pattern from that due to digitalis effects

3 Acute Pericarditis In uncomplicated cases acute pericarditis can easily be differentiated from acute anterior infarction since in the former the initial upward deflection is absent in Leads IV_F and IV_R and is elevated in the old Lead VI Moreover the findings in the subacute stage cove-shaped T wave and tall amplitude T waves are absent in acute pericarditis[40]

6 *Posterior Myocardial Infarction* Posterior myocardial infarction (Fig 24) is due to occlusion either of the circumflex branch of the right coronary artery near its orifice or the posterior descending branch in the region of the crus (junction of right circumflex with posterior descending

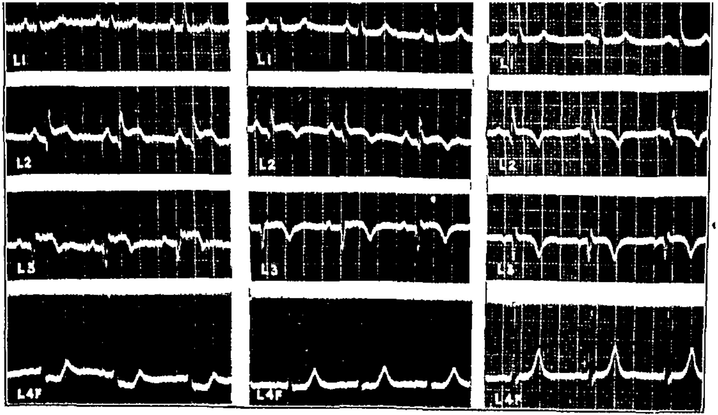


FIGURE 21 Posterior myocardial infarction *A* was taken 24 hours after the onset of acute precordial pain Note slight R T depression in Lead I R T elevation in Leads II and III and a deep Q wave in Leads II and III IV_F shows maintenance of the R wave with S T depression These findings are characteristic of the acute stage of posterior myocardial infarction Note that the indirect leads give somewhat more information than the precordial lead *B* was taken five days after *A* Note slight R T depression in Lead I slight R T elevation in Lead II not as marked as in *A* *The Q waves are not as deep* Lead III now shows deeply inverted T waves but only slight R T elevation In IV_F the R T depression has entirely disappeared These findings are fairly characteristic of the subacute stage of posterior myocardial infarction *C* was taken two weeks after *B* Note absence of marked S T depression in Lead I T_2 and T_3 are now inverted The T waves are still inverted in Leads II and III and Q waves are still present but R T elevations in Leads II and III are slight IV_F shows no change except that the amplitude of the T wave is slightly higher than in *B* These findings are typical of the subchronic stage of posterior myocardial infarction *During the chronic stage the Q wave in Leads II and III may entirely disappear and T_3 may become upright*

branch of right coronary artery). The typical pattern observed in such cases is as follows:

1. Acute Stage (stage of R-T deviation): The R-T segment is depressed in Lead I and elevated in Leads II and III, or in Lead III alone, in the presence of a left axis deviation (Fig. 24 *A*). With a bicardiogram, the R-T segment is elevated in Leads II and III: The R-T segment of Lead I is unaffected. A Q wave is often observed in Lead III, or Leads II and III. This is often referred to as the T_3, or Q_3-T_3 type of Q-R-S-T change. The precordial Lead IV_F shows a depression of the R-T segment without change in the initial upward or downward deflection. The R-T deviation in IV_F (mirror image of old Lead V) is usually greater than in IV_R (mirror image of old Lead IV).

2. Subacute Stage (stage of rapidly changing T waves): With the disappearance of the R-T deviation, T_1 tends to become upright, T_2 and T_3 *inverted; these are often cove-shaped (Fig.* 24 *B*). T_3 and T_4 (IV_F) often show marked increase in amplitude (Fig. 23 *C*). The depth of the T wave inversion and increased amplitude tends to diminish as healing progresses.

3. Chronic Stage (stage of permanent change in Q-R-S-T complexes): In the chronic stage, the T_2 and T_3 often remain inverted or T_2 may return to an upright configuration. Q_2 and Q_3 if present in the acute and subacute stage, become smaller. Frequently Q_3 persists permanently but it may disappear entirely. T_4 returns to normal. In the healed stage of a posterior infarction there is often little and may be no electrocardiographic evidence of a previous coronary accident.

4. *Variations of the Usual Patterns in Posterior Infarction.* The following deviations from the usual pattern of posterior infarction are observed:

(1) Where the occlusion develops gradually, the R-T deviations may not develop until two or three days after the inception of precordial pain. They may be entirely absent and only inverted T waves may be observed. In the slowly developing occlusion, R-T deviations may be slight or absent in the precordial leads.

(2) Where there has been a previous old anterior infarction, acute infarction of the posterior wall is characterized by the typical changes enumerated above. In addition, T_1 may be inverted and there is fre-

quently an absence of the initial upward deflection with some depression of the R-T segment, these additional findings being a result of an old anterior infarct.

(3) Posterior infarction, even when it develops suddenly, not infrequently fails to produce R-T deviations in the precordial leads, although manifesting characteristic changes in the indirect leads. These may at times be elicited by shifting the precordial electrode to different portions of the precordium.

5. ELECTROCARDIOGRAPHIC PATTERNS SIMULATING ACUTE POSTERIOR INFARCTION: The electrocardiographic changes in posterior infarction are to be differentiated particularly from digitalis effects. In the presence of a bicardiogram, the differentiation is usually not difficult, since digitalis usually produces a depression of the S-T intervals in all three indirect leads When digitalis produces T waves that are of the myocardial type (*e. g.*, with upward convex S-T intervals), the differentiation is more difficult. Even so, there are differences which make the differentiation possible Posterior infarction causes an elevation of T_2 and T_3 which is not produced by digitalis in a bicardiogram. If no elevation is present, the T waves are usually more deeply inverted and coved in occlusion than they *are with digitalis The presence of a conspicuous Q wave in Lead III is* frequently observed and is characteristic of an occlusion; this change is not produced by digitalis.

With left axis deviation, the R-T deviation in Leads I and III produced by digitalis may be similar to those of posterior infarction. However, digitalis frequently shortens the Q-T interval and presents a type of R-T deviation (upward concave rather than convex) which is frequently typical.

The precordial rather than the conventional leads often furnish the best evidence for differentiating between occlusion and the effects of digitalis, in the absence of left axis deviation. The R-T deviations show a higher elevation in IV_F than IV_B. The reverse is true in posterior infarction. In the presence of left axis deviation, this change is not present and, therefore, of no differential help. The differentiation must be made on such findings as the prominent Q waves in Leads II and III and appearance in the subacute stage of cove-shaped deeply inverted T waves in Lead II and III and high amplitude waves in the chest leads

C. ANTEROPOSTERIOR MYOCARDIAL INFARCTION

The anteroposterior type of myocardial infarction (Fig. 25) is due to occlusion of anterior descending branch of the left coronary artery

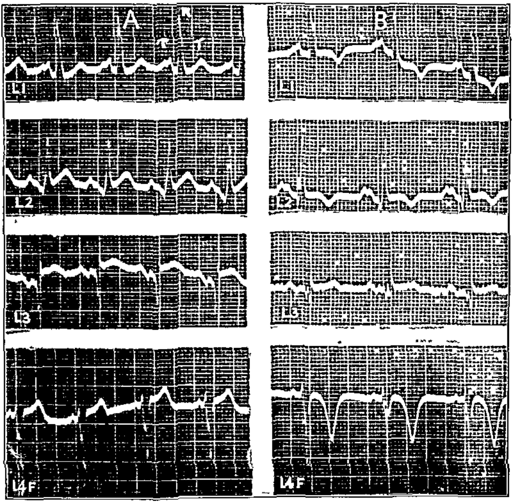


FIGURE 25 Anteroposterior myocardial infarction Features of both anterior and posterior infarction are seen *A* was taken 24 hours after the onset of acute precordial pain Note slight depression of S T_1 and elevation of S T_2 and S T_3 and the presence of a Q wave in Leads II and III IV_F shows a very small R wave with slightly elevated R T segment The presence of elevated R T segments in II and III plus a Q_2 and Q_3 are evidence of posterior infarction The slightly elevated R T and small R_4 suggest anterior involvement *B* was made three weeks after *A* T_1 and T_2 are now inverted with absence of R-T elevation Q_2 is small but Q_3 is definite with very slight elevation in this lead Note very small R wave in IV_F and deeply inverted T wave of considerable amplitude in this lead

The posterior wall of the left ventricle as well as the anterior wall and apex is involved in those hearts where this branch supplies a considerable portion of the posterior wall of the left ventricle near the apex and where

the blood supply to this region by other arteries is inadequate. The latter results when the posterior descending branch of the right coronary artery is small or it may be a result of a previous posterior occlusion.

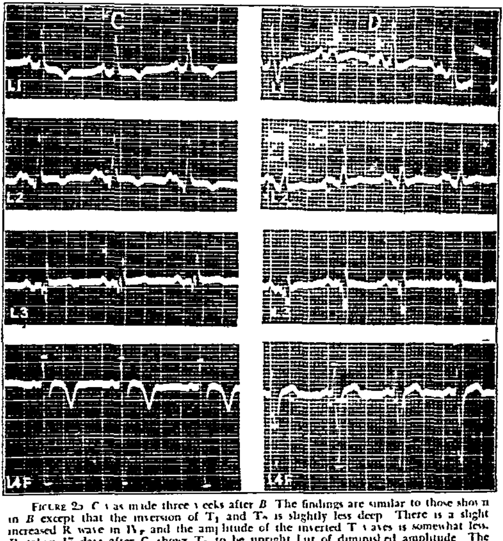


FIGURE 25. *C* was made three weeks after *B*. The findings are similar to those shown in *B* except that the inversion of T_1 and T_4 is slightly less deep. There is a slight increased R wave in IV_F and the amplitude of the inverted T waves is somewhat less. *D* taken 17 days after *C* shows T_1 to be upright but of diminished amplitude. The Q waves of Lead III are prominent. A small R wave is observed in IV_F and the formerly inverted T wave has now become upright. These represent the maximum changes in this case. No further improvement was noted.

The electrocardiographic pattern presents characteristics of acute anterior as well as posterior infarction. The R-T segment is elevated in all three limb leads, greatest in Lead II; a Q wave is present in Leads II and III; the initial upward deflection is absent and the R-T segment is elevated in Leads IV_F and IV_R.[45] Evidence of posterior involvement is indi-

cated by the elevated R T segment in Leads II and III and the Q_2 and Q_3; anterior by the elevated R T segment in Lead I and the absence of the R wave and elevated R-T segment in IV_F.

The chief conditions to be differentiated from this type of infarction is acute pericarditis This can usually be done successfully through the

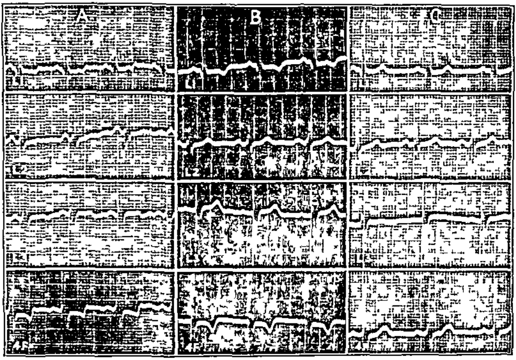


FIGURE 26 *Lateral infarction A, Note the slightly inverted T_1 with slightly* depressed R T segment and slightly elevated T_3 with a left axis deviation IV_F shows a maintenance of the R wave with definitely depressed R T segment and tendency to inverted T This tracing was taken 36 hours after the onset of acute precordial pain *B* was taken four days after *A* Note the T wave in Lead I is now definitely inverted with only a slight tendency to depression of the R T segment T_3 is upright with slight elevation of the R T segment The T wave in Lead IV_F is definitely inverted the R T segment is only slightly depressed *C* was taken three weeks after *B* T_1 is now upright T_2 is now upright and T_3 is somewhat flat No R T deviations are observed. T_4 is now upright and no deviations of the R T segment are observed This represents the chronic stage of the infarction Evidences of a previous coronary occlusion could not be recognized from this tracing alone This emphasizes the importance of taking serial tracings in the presence of precordial pain

fact that in acute pericarditis, Q_2 and Q_3 are absent, the initial upward deflection is present in IV_F and IV_B and the typical coving and tall amplitude T waves of the chest leads are absent in the subacute stages

D. INFARCTION OF LATERAL WALL OF LEFT VENTRICLE

The pattern observed in infarction of the lateral wall of the left ventricle (Fig 26) was recently described by Wood, Wolferth and

Bellet[47] It is due to occlusion of the circumflex branch of the left coronary artery which supplies the lateral wall of the left ventricle and a portion of the posterior wall The main features are

A depression of the R T segment in Leads I and II a depression of R S T in IV_F and preservation of the initial upward deflection and an absence of the signs of posterior infarction in Lead III With healing all the signs disappear and the electrocardiogram may return entirely to normal (Fig 26 C) Infarction involving the anterolateral wall of the left ventricle without involving the apex have shown an electrocardiographic pattern characterized by R T elevation in Lead I R T depression in Lead III with a preservation of the initial upward deflection in IV_F throughout the acute subacute and chronic stages of infarction

The electrocardiographic pattern of lateral infarction might be confused with that of posterior infarction pulmonary embolism and digitalis effects Posterior infarction can usually be differentiated because it has a significant Q_3 and elevation of R S T_2 and R S T_3 Pulmonary embolism differs in that T_1 is usually upright T_3 inverted a Q_3 is often present and a deep S_1 is frequently observed with a tendency to right axis deviation

Digitalis effects often may be ruled out in the manner similar to that described under posterior infarction At times however it may be difficult to definitely make this differential diagnosis from the electrocardiographic findings alone

E CONDITIONS UNDER WHICH THE ELECTROCARDIOGRAM FAILS TO REVEAL EVIDENCE OF MYOCARDIAL INFARCTION

The diagnosis of myocardial infarction may not be indicated by the electrocardiogram under the following circumstances

1 The electrocardiographic changes may be so evanescent that they may fail to be recorded if too few electrocardiograms are taken If late in appearance they may fail to appear in earlier tracings For example the maximum electrocardiographic alterations after anterior infarction at times do not appear until 24 to 48 hours or even longer after the occlusion In such instances tracings taken immediately or soon after the onset of pain would show little change

2 The presence of R T deviations due to digitalis may confuse the diagnosis

3 In the presence of bundle-branch block R T deviations are often observed independent of infarction and in left bundle branch block the R

wave of IV_F is extremely small (1 to 3 mm) These factors render the diagnosis of myocardial infarction difficult However, *the complete absence of the* R wave in Lead IV_F and the presence of marked R T deviations in limb and precordial leads are of help in the diagnosis

4 The presence of low amplitude waves in indirect leads results in correspondingly small R T deviations which may not be readily recognizable the findings in the precordial leads however, may be helpful and definite

5 The presence of auricular fibrillation by deforming the R T segments may hinder the diagnosis under these circumstances the precordial leads are also of help

6 In the presence of ectopic rhythm with aberrant ventricular complexes (*e g*, ventricular tachycardia), the recognition of an acute occlusion is often impossible

7 When the infarct is small has as yet not reached the epicardial surface is located in the septum or some silent area which affects the indirect and the usual precordial leads slightly or not at all the electrocardiogram may fail to reveal evidence of infarction In such cases evidence of relatively rapid changes in the configuration of the T wave without S T deviation characteristic of infarction in the presence of a suggestive history is to be considered as very suggestive evidence of coronary occlusion

VIII ACUTE PERICARDITIS

Acute pericarditis due to various causes (*e g*, rheumatism pneumonia various septic conditions, intrapericardial rupture of aneurysm and uremia), often produces an electrocardiographic pattern that is quite characteristic [46] The electrocardiographic findings are explained in most instances by the fact that the inflammation is not limited to the pericardium but spreads to and affects the subepicardial portion of the myocardium The muscle injury thus produced and not pericarditis *per se* is therefore responsible for the electrocardiographic alterations observed

A THE ACUTE STAGE (Stage of R-T Deviation)

The pattern is characterized by an elevation of the R T segments in all three leads or at least in Leads I and II by elevation of R T in IV_F and IV_B and elevation of the old R T_{VI} and by a preservation of the initial upward deflection in IV_B and IV_F (Fig 27)

B SUBACUTE STAGE (Stage of Rapid T Wave Changes)

The R T elevation gradually disappears and gives way to inverted T waves in Leads I and II or all three leads (Fig 27 *B*) These T waves show only slight to moderate inversion and do not present the cove shaped

configuration of subacute infarction, nor are very tall T waves observed in this condition. Occasionally the elevated R-T segment changes to a normal upright T wave without going through the stage of inversion.

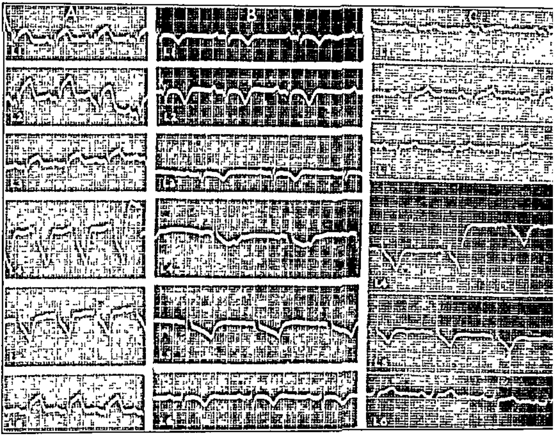


FIGURE 27. Acute pericarditis. *A* was taken 24 hours after diagnosis of acute pericarditis was made. This tracing shows the typical pattern observed. Because the old Lead VI gives important information, the chest leads shown were made by the original method. The R-T segment in all three leads is elevated. The R-T segment of Lead IV is depressed with the maintenance of the initial downward deflection. R-T of Lead VI is elevated. The R-T segment of Lead V is only slightly depressed. *B* was taken four weeks after *A*. Note that T_1 and T_2 are now deeply inverted and possess a somewhat cove-shaped configuration, resembling to some extent that observed in anterior myocardial infarction: The persistence of the initial deflection in Lead V is the chief differentiating point. The segment is no longer deviated in the precordial leads. These findings are observed during the subacute stage of the myocardial change, incident to acute pericarditis. *C* was taken eight months after *B*. T_1 and T_2 are now upright. Leads IV, V, and VI are now normal. The entire tracing has now returned to a normal configuration. The tracing alone would give no clue to the previous presence of a serious heart lesion.

C. CHRONIC STAGE

The inverted T wave may be permanent. In many instances they gradually become flattened and finally return to a normal upright configuration (Fig. 27 C). The T wave changes in the precordial leads closely follow those of the limb leads.

All of these stages are not often observed in the same patient In certain etiologic types, *e g*, pneumonia and septic stages, only the acute and subacute stages are observed, since survival is rare Tuberculous pericarditis usually begins insidiously and is therefore, not seen until the subacute stage is established The chronic stage can also be studied as a rule, since the disease lasts at times for long periods and occasionally ends in recovery R T deviations in tuberculous pericarditis is rare In cases of rheumatic pericarditis one may be able to observe all three stages in the same patient

The differential diagnosis in this condition is to be made from antero posterior myocardial infarction this has already been discussed The only circumstances in which this differentiation is difficult is when the pericarditis is associated with myocardial infarction

IX. PULMONARY EMBOLISM AND COR PULMONALE

The electrocardiographic changes in pulmonary embolism are due to two factors The presence of right ventricular strain and the associated anoxemia In its fully developed form the electrocardiogram is characterized by a slightly low origin of T_1, a depression of the S T interval in Lead II, a prominent S wave in Lead I, a Q_3 and inversion of T_3 The Q T interval is lengthened in some cases Lead IV_F shows a depressed *R T* segment with no change in the initial upward deflection With recovery those changes that are present completely disappear [48 49]

The changes above described are observed only in those cases of pulmonary embolism where the embolus is large They are to be expected in only a small number of cases In many only a right axis deviation or a Q_3 *is observed In some instances no striking changes are present*

The right ventricular strain produced suddenly by acute pulmonary embolism can be gradually produced by chronic changes in the lung parenchyma, by arteriosclerosis of the pulmonary arteries or by obstruction to flow of blood from the right heart in congenital and some forms of acquired heart disease The most important finding in the electrocardiogram in such conditions is a right axis deviation

X THE ELECTROCARDIOGRAM IN ALTERED METABOLIC STATES

A Diabetic Acidosis In diabetic acidosis the myocardium may be profoundly *affected In practically every instance of coma and in most*

cases of lesser grades of acidosis, the electrocardiogram is definitely and rather characteristically changed.[25] The unusual feature of this is that the maximum degree of abnormality develops not at the height of the acidosis but some 24 hours later when the blood chemistry findings have returned to normal. The rather distinctive alterations observed are lengthening of the Q-T intervals, inversion of T_1 and T_2 and depression of the S-T interval. One or more of these changes are observed in nearly all cases of diabetic acidosis in whom several tracings are taken. These changes return gradually to normal, usually within a week after recovery from the acidosis.

B. Acidosis (Nondiabetic): In cases of nondiabetic acidosis, inversion of T waves in Leads I and II have been observed. These returned gradually to normal with improvement in the acidotic state.

C. Alkalosis: Alkalosis produced by voluntary overventilation or by ingestion of sodium bicarbonate may result in a reduction of the amplitude of the T waves. Lengthening of the Q-T interval has also been observed. The chemical changes must be quite marked before electrocardiographic alterations are produced.

D. Hypoglycemia: The effect of hypoglycemia upon the heart depends to a large extent upon the cardiac status. In the presence of already existing myocardial disease, severe additional damage may result. Serious electrocardiographic alterations have been recorded during the hypoglycemic state in such patients, *e.g.*, inversion of T_1 and T_2; depression of the S-T segments; ventricular extrasystoles and auricular fibrillation These changes are not always reversible.[50]

In normal hearts, the effects of severe hypoglycemia has been studied during the insulin shock treatment of schizophrenia.[51] In this state, the blood sugar is reduced to 10 to 15 mg per 100 cc., this level being maintained for several hours The electrocardiogram in such patients shows changes in about 50 per cent of cases. They are of a less severe grade than in patients with diseased hearts and consist of flattening of the T wave, depression of the S-T segment, lengthening of the Q-T interval, sinoauricular heart block and rarely, auricular fibrillation (2 out of 40 shock treatments).

E. Hypocalcemia: In hypocalcemia, when the level of the serum calcium drops to a figure below 6 to 7 mg. per cent, changes are observed

profoundly affects the heart, the changes that occur in the electrocardiogram are not discussed here since they are generally thought to be the result of chronic effects rather than the acute disease. The changes observed are in many instances reversible and disappear with the termination of the infection. In other types, particularly rheumatic fever, permanent cardiac damage results. The electrocardiographic changes in the more important infections will be described below.

A. **Rheumatic Fever:** In rheumatic fever, certain changes are observed with the acute and active stage of the disease; others with the chronic stage [53, 54]

(a) *In the Acute Stage:* It is to be pointed out that not all nor even any of the following changes need necessarily be present. However when they do exist, they may be of considerable diagnostic and prognostic value.

1. R-T ELEVATION: These may be the result of large areas of focal myocarditis, often apparently, they are due to subepicardial involvement of the myocardium, secondary to acute rheumatic pericarditis.

2. T WAVE CHANGES: The T waves may be of low amplitude, diphasic, inverted, notched and occasionally they manifest bizarre shapes that are difficult to describe.

3. CONDUCTION DISTURBANCES: The most frequent and consistent change is prolongation of the A-V conduction. This is frequently so transient that it may be present one day and absent the next. Higher grades of A-V heart block, 2:1, 3:1 are infrequent; complete A-V heart block is rare. Bundle branch block is seen occasionally.

4. ARRHYTHMIAS Various arrhythmias may be observed. Extrasystoles are frequent, sinoauricular heart block, auricular fibrillation and flutter are occasionally encountered

(b) *In the Chronic Stage* All of the changes may disappear with subsidence of the acute disease and the electrocardiogram return entirely to normal, usually, however, some change remains permanently. Where the myocardial damage has been considerable, inversion of the T wave and auricular fibrillation may persist if they originally appeared during the acute stage of the disease or they may appear as a development in the course of rheumatic heart disease long after the acute process has subsided. Other arrhythmias may also appear. With various valvular lesions, axis deviation may become a permanent change: Right axis deviation with mitral stenosis and left axis deviation with aortic disease. The

P waves may be notched and their base broadened with severe auricular muscle damage. Bundle branch block, right and left, may develop as a result of scar formation in these regions.

B. Scarlet Fever: Occasionally, scarlet fever produces the same cardiac changes that result from rheumatic fever. When this is the case, the same electrocardiographic changes that develop in rheumatic fever may be seen. In our experience, they are apt to be less severe.

C. Acute Nephritis: Acute glomerulonephritis, particularly as it occurs in children and young adults is not to be considered as a local condition involving only the kidney, but rather a systemic disease in which many organs including the heart may also be involved. The smaller blood vessels throughout many of the organs of the body are the seat of acute changes. Evidence of cardiac involvement may be noted clinically by cardiac enlargement, tachycardia, alteration of heart sounds and even congestive failure. The electrocardiogram often presents evidence of severe myocardial damage,[7] T_1 and T_2 may be flattened or inverted; the P-R interval prolonged; the initial upward deflection in Lead IV_F may be considerably diminished in amplitude and T_4 may be inverted. While all of these changes may be seen in the same individual, this is not often the case. Usually electrocardiographic changes are not marked and *occasionally, none may be seen. Changes that are produced may return* to normal with diminution of the infection.

D. *Pneumonia:* *Pneumonia may produce severe cardiac damage; in* some instances, death may result from this cause. Evidence of myocardial derangement *may sometimes be revealed by serial electrocardiographic* tracings.[56] R-T elevations are usually the result of myocardial involvement *due to spread from a pneumonic pericarditis and when present* should suggest this condition. Flattening of the T waves and depression of the *S-T interval, prolongation of the A-V conduction time and sinus* bradycardia (rate 40 per minute) are not infrequent. Manifestations of *severe myocardial derangement such as actual inversion of the T wave,* the inception of auricular fibrillation and flutter are much less frequent; *when they develop, they indicate a poor prognosis. Since, with the excep*tion of pericarditis, these changes are a result of toxemia, are usually *reversible and disappear with the subsidence of the disease. However, at* times these changes along with clinical evidence of myocardial weakness *may persist for some time.*

E. Diphtheria: Diphtheria not infrequently affects the heart muscle. It produces a severe type of interstitial myocarditis and is accompanied by an intense grade of myocardial degeneration.

In 50 per cent of 15 cases of severe and moderately severe diphtheria, inversion of T waves were observed during the acute illness and in convalescence; these returned to normal after several weeks.[58] Disturbances of intraventricular conduction have also been observed; these have been ascribed to toxic depression of the conduction system. Prolongation of A V conduction occurs not infrequently. In 19 cases of complete heart block occurring during the course of acute diphtheria, all terminated fatally.[59]

If the disease is survived, electrocardiographic and clinical evidence of heart disease disappear.

XII. THE ELECTROCARDIOGRAM IN HYPERTENSION, CHRONIC NEPHRITIS AND UREMIA

A. Hypertension: The electrocardiogram is quite characteristic with well established hypertension. There is usually a left axis deviation, frequently a small or moderate Q wave in Lead I and T wave inversion in Lead I or Leads I and II. The S-T interval is usually indistinct, beginning to slope downward immediately after the completion of the S wave. While not markedly coved, it is generally upward convex to some extent While it is somewhat unsettled as to whether these alterations are a result of muscle strain and fatigue or insufficient blood supply due to the fact that the capacity of the coronary circulation is overtaxed by the increased mass of the hypertrophied muscle, or by actual change in the coronary arteries, the fact remains that these electrocardiographic changes are quite constant and characteristic.

B. Uremia: In chronic nephritis and uremia, we are usually dealing with a heart which has been subjected to the strain of hypertension and accompanying changes for a long time. As a result, the heart is usually considerably enlarged and often the seat of various grades of myocardial disease. Electrocardiographic characteristics of hypertensive heart disease (left axis deviation and inverted T waves), are therefore usually seen With retention of nitrogenous products, additional severe acute degeneration of the myocardium may result.[60] With this, the electro-

cardiogram usually becomes more abnormal. If the T waves were not already inverted, they are apt to become more abnormal. If originally upright, they may invert. Arrhythmias (*e.g.*, sinoauricular heart block and nodal rhythm) are occasionally encountered. With the onset of pericarditis, *R-T elevations may be noted in limb and precordial leads.* While it is difficult to describe all the variations, it is our experience that serial tracings made during long-standing uremia tend to show a progressive increase in the severity of the electrocardiographic findings.

XIII. THE ELECTROCARDIOGRAM IN AVITAMINOSIS

Disturbances of cardiac function may develop as the result of an unbalanced food intake, particularly when there is a deficiency of vitamin B_1. Previously normal as well as diseased hearts may be affected. *The cardiovascular manifestations are ascribed partly to involvement* of the nervous system and partly also to change in the heart muscle. In severe cases, right and left-sided failure may result. The chief changes *observed are simple tachycardia, sinus bradycardia, T wave changes* (flattening and inversion of T_1 and T_2), low amplitude of the ventricular complexes and lengthening of the Q-T interval. With rest, and a suitable dietary regimen, the evidence of cardiac abnormalities often rapidly disappear.[61]

Pellagra is often associated with evidence of cardiovascular abnormalities, dyspnea on effort, palpitation, tachycardia and slight edema. Feil,[62] studying the electrocardiogram in cases of pellagra, noted inversion of T_1 and T_2, elevated and cove-shaped R-T segments and prolongation of the Q-T interval.

XIV. THE ELECTROCARDIOGRAM IN ANEMIA

Anemia, if marked and prolonged for any period of time produces changes in the heart muscle; among these are cardiac enlargement due to dilatation and fatty degeneration.

The commonest electrocardiographic changes are alterations in the T wave (depressed S-T segment and inversion of T_1 and T_2). Nodal rhythm and lengthening of the Q-T interval have also been observed. The severity of the electrocardiographic changes appear to be related to the degree of anemia and usually have been found to return to normal with improvement in the blood picture.[63]

XV. THE ELECTROCARDIOGRAM IN CARDIAC SYNCOPE

Syncopal attacks are not particularly common in heart disease. We have already referred to syncope as an occasional manifestation of very rapid heart rates particularly auricular flutter with a 1:1 A-V ratio. We wish under this heading to refer to two other varieties of syncope in which derangement of the normal cardiac mechanism plays a rôle. These are: (1) The syncope occurring in Stokes-Adams seizures, and (2) that produced by vagal impulses which originate in the carotid sinus. The former is always seen in severe heart disease; the latter may develop in the presence of entirely normal hearts.

A. Stokes-Adams Seizures: Stokes-Adams attacks are due to either failure of normal ventricular contraction in the course of complete A-V heart block or during the transition from normal sinus rhythm or partial block to complete A-V heart block. Periods of asystole, lasting three to nine seconds are sufficient to produce syncopal attacks alone or accompanied by convulsive seizures. The following mechanisms have been recorded by the electrocardiograph during such attacks: Prefibrillatory types of ventricular tachycardia; ventricular fibrillation; ventricular standstill with continuation of auricular beating and standstill of the whole heart. These may occur singly or in various combinations; all of these may at one time or another be observed in the same patient.

B. Carotid Sinus Syncope: Another type of syncope occurs in man due to vagal reflexes which originate in the carotid sinus These are often the result of reflex disturbances from an extracardiac location and occur in patients with normal rhythm. They occur spontaneously, can be induced by carotid sinus pressure and may be abolished by atropine. Three types of carotid sinus syncope, depending upon the different path way involved, have been described[64]

(1) *The Vagal Type:* In this variety symptoms result from cerebral anoxemia The latter is produced chiefly by a diminution in the number of ventricular contractions which results from vagal influences on the sinoauricular and auriculoventricular nodes. Associated with this, is a fall in blood pressure If the vagal effects are slight and only produce a moderate slowing of the auricles, the symptoms will be slight. However the electrocardiogram reveals that the vagal effects may be marked and may result in complete suppression of auricular contractions or in varying grades of partial or complete A-V heart block during periods of

stimulation. When these responses occur, cerebral anoxemia is sufficient to produce syncopal attacks.

(2) *The Depressor Type:* This form is rare by itself; it usually occurs in association with the other two varieties. The afferent impulse is set up as in the vagal type from the carotid sinus while the efferent impulse acts on small blood vessels by way of the aortic depressor nerves The symptoms result from primary reflex, vasodilatation and secondary depression of the blood pressure, entirely unrelated to cardiac slowing and cardiac arrhythmia. Atropine has no effect on the signs and symptoms since they do not result from cardiac slowing.

(3) *Cerebral Types:* The symptoms result from impulses that travel directly to the brain. No significant changes occur in the heart rate or blood pressure and the total flow of blood through the brain is normal. Neither atropine nor epinephrine help these attacks.

XVI. ELECTROCARDIOGRAPHIC CHANGES PRODUCED BY DIGITALIS

This subject is discussed and illustrated in Chapter XXXVI For this reason, it has been referred to only indirectly.

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CHAPTER XXIX

ROENTGENOLOGY OF THE HEART AND GREAT VESSELS

By Alexander Margolies M D

Introduction A critical survey of the patient with cardiac disease is incomplete without a careful roentgen examination of the heart and its pedicle Considerable knowledge has accumulated since the introduction of the method so that the opinion of Sir James Mackenzie concerning its lack of helpfulness may now be safely disregarded Compared with the physical examination the information to be derived from the use of the x rays may be confirmatory contradictory additional and even unexpected Considered alone however it may fail at times to be diagnostic and rarely may be misleading Preferably the roentgen examination should be performed by the clinician so that he may correlate the findings with those obtained from other methods of examination

A careful roentgen study should include observations of the position and mobility of the heart the cardiac and vascular configuration and distortion due to generalized or localized enlargements or abnormal rotation the character and extent of the pulsations the presence of abnormal densities such as calcification in the aortic wall pericardium myocardium valves and coronary arteries the presence of abnormal hilar pulsations and densities and pulmonary congestion Last and perhaps most important is the measurement of heart size

These observations may be influenced or even rendered ineffectual[1] by such conditions as chest deformities pneumothorax pleural effusions abnormal densities in the lungs atelectasis adhesions abnormal height or mobility of the diaphragms herniation of the stomach or intestines through the diaphragm mediastinal shift etc

X RAY METHODS

The routine roentgen methods employed are simple inspection (roentgenoscopy or fluoroscopy) and roentgenography The two roent

genographic methods, teleoroentgenography and orthodiagraphy, are employed chiefly for the determination of cardiovascular dimensions. Teleoroentgenography consists in making a film exposure with the x ray tube at a considerable distance from the patient and the film, to avoid the distortion due to (1) the divergence of the rays from the tube target and (2) the variable distances from the film of the different parts of the heart and vessels.[2, 3] The magnitude of the error due to these two factors *is probably not sufficiently appreciated In a recent study of 130 pa*tients,[4] the transverse diameter of the heart in posteroanterior teleoroentgenograms at two meters, averaged 6 6 per cent larger than the transverse diameter in orthodiagrams At a target film distance of 48 inches, and an object film distance of four inches, the magnification is approximately 14 per cent On the other hand, the cardiothoracic ratio in teleoroentgenograms is less than in orthodiagrams, because in the former, the magnification of the chest is greater than that of the heart. The vascular pedicle is magnified even more than the heart, because of its more posterior position.

Orthodiagraphy may be performed in several ways: (1) The screen, patient and tube are fixed, the tube being at approximately two meters from the screen; the cardiovascular silhouette is drawn on the lead glass *of the screen.* (2) The standard fluoroscope is equipped with a lead dot* marking the position of the central x-ray beam on the screen; the screen and tube are mounted together on one carriage, and moved so that the lead marker travels along the contour of the cardiovascular shadow; at the same time, points on the contour are recorded, by means of a cable release mechanism, on paper placed on an attachment at the side of the fluoroscope. (3) The patient and screen are fixed; the tube is separately mounted and freely movable; the tube shutter is closed down to permit *only a small pencil of central perpendicular rays to be used, the result*ing small fluorescent screen field is then moved along the cardiovascular and chest contours which are simultaneously sketched on the lead glass of the screen; the contours are then copied on transparent paper This method is, perhaps, the one most widely used.

The advantages of teleoroentgenography are objectivity and the inclusion of lung detail. The disadvantages are cardiovascular magnification

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* Inadvisable because of the necessity of greater x ray quantities at great distances and the scattering of rays

and distortion; omission of the study of mobility and pulsations; inability to localize calcifications by their characteristic movements; the not infrequent inability to differentiate the cardiac contour from spinal and lung densities, or apical fat; increased expense, particularly if oblique and lateral views are included; delay due to film processing. Orthodiagraphy, if expertly done, overcomes these disadvantages, but has one of its own, namely, subjectivity. The importance of this personal element usually diminishes with increasing skill in the method. Furthermore, the fluoroscopic method individualizes the patient in that it permits immediate study in any desirable angle of rotation as indicated by the pathology present and the size, shape and position of the heart. An additional advantage of the orthodiagraphic method is that it permits easy comparison of successive orthodiagrams of the same patient, by the overlaying of the transparent copies.

Special roentgenographic methods, such as roentgenkymography and the visualization of the cardiac and vascular cavities by the intravenous injection of opaque substances, will be discussed later.

ANATOMICAL CONSIDERATIONS

The heart and great vessels, as seen in the film and at the fluoroscopic screen, produce an almost homogeneous and undifferentiated shadow. It is necessary, therefore, to study the periphery of the silhouette to determine the presence of abnormal contours of the various chambers and vessels. This presupposes a knowledge of cardiovascular topography and the contribution of the component parts to the borders of the silhouette in various views Furthermore, it is essential to know the relations of the esophagus, trachea and bronchi to the heart and its pedicle, because displacement of these structures may throw considerable light on localized enlargements, deformities or malformations

POSITION OF THE PATIENT

It is assumed in the discussion which follows, that the patient is standing erect. Other postures may be used for special purposes. There are four standard positions of the chest with respect to the plane of the screen or film (1) Anteroposterior position,* (2) first or right anterior oblique position, (3) second or left anterior oblique position, (4) left lateral position.*

* The posteroanterior and right lateral positions cause greater magnification and distortion in the teleoroentgenogram because of the greater distance of the heart from the film

The normal contours in these positions are as follows:

1. In the anteroposterior position (Fig. 1), the right border of the silhouette, from above downward, consists of the innominate vein, superior vena cava, and the right auricle.* Occasionally, on deep inspiration, the vertical right border of the inferior vena cava may be visible below the right auricle in the right cardiodiaphragmatic angle, par-

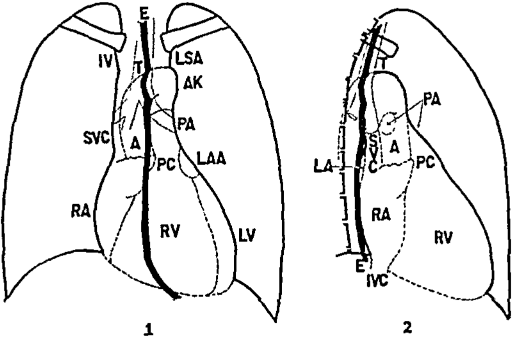

FIGURE 1 Anteroposterior view FIGURE 2 Right oblique view (45 degrees)

The broad irregular band marks the course of the esophagus; the heavy continuous lines indicate the visible contours of the heart and chest, the interrupted lines outline the invisible contours of the chambers, vessels, trachea and bronchi *IV*, Right innominate vein, *SVC*, superior vena cava, *IVC*, inferior vena cava, *RA*, right auricle, *RV*, right ventricle; *PC*, pulmonic conus, *PA*, pulmonary artery; *LA*, left auricle, *LAA*, left auricular appendage; *LV*, left ventricle, *A*, aorta, *AK*, aortic knob, *LSA*, left subclavian artery (and vein?); *E*, esophagus; *T*, trachea.

ticularly in tall thin individuals with vertically-placed hearts. The aorta normally does not overlap the superior vena cava in this view.[3,5] Normally, also, the right supracardiac border is well within the line of the right auricle.

The left border consists of the left subclavian artery or left innominate vein or both, the aorta, pulmonary artery, left auricular appendage and left ventricle. The aorta in this view presents a rounded prominence,

* The borders referred to here and hereafter are only those that are clearly discernible in the film and at the fluoroscopic screen.

the aortic arch, which causes its displacement again to the mid-line, thus producing the first curve or aortic impression. Because of the left posterior course of the aortic arch, the esophagus is deviated to the right and posteriorly, and best seen in the anteroposterior, right oblique and lateral views (Figs. 1, 2 and 4). The second curve, directly below the aortic impression, is produced by pressure of the left bronchus,[8] and is easily visible in the right oblique and lateral views (Figs. 2 and 4). This deviation is more directly posterior than that of the aortic impression, but is also directed somewhat to the right. The left bronchus impression has been frequently and erroneously referred to as the pulmonary artery impression, but more careful study such as Evans', reveals that the pulmonary artery is more anteriorly placed and nowhere in contact with the esophagus. The error has been due doubtless to failure to consider the effect of parallax in oblique views. The third curve is due to contact of the esophagus with the left auricle, and is normally not so well marked as the first two impressions. It is directed posteriorly. The normal left ventricle usually does not cause any impression. Just above the diaphragm the esophagus deviates to the left and is occasionally pressed upon posteriorly by the descending aorta, which at this level occupies the median line, the two structures thus crossing each other obliquely, causing the fourth or descending aorta impression.

In a recent study of the cardiovascular relations of the esophagus, Evans[8] has emphasized the value of its visualization in facilitating more accurate diagnoses of cardiovascular disease. The chief conditions in which it is diagnostically helpful are mitral stenosis, aortic dilatation and tortuosity, aneurysm and congenital anomalies of the aorta, such as dex

of the left auricle and left ventricle On deep inspiration, a reflection of the parietal pericardium may be seen as a vertical shadow extending from the left ventricular border to the diaphragm, particularly in thin individuals The clear space between the heart and sternum is called the retrosternal triangle and that between the heart border and the spine is called the retrocardiac space It should be emphasized that the right leaf of the diaphragm forms the base of the retrocardiac space The left

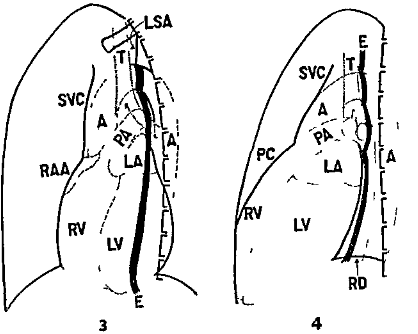

FIGURE 3 Left oblique view FIGURE 4 Left lateral view (15 degrees)

The broad irregular band marks the course of the esophagus the heavy continuous lines indicate the visible contours of the heart and chest the interrupted lines outline the invisible contours of the chambers vessels trachea and bronchi *SVC* superior vena cava *RV* right ventricle *PC* pulmonic conus *PA* pulmonary artery *LA* left auricle *LV* left ventricle *A* aorta *LSA* left subclavian artery (and vein?) *E* esophagus *T* trachea *RD* right diaphragm

diaphragm may be seen at a lower level A not inconsiderable part of the heart lies below the level of the right diaphragm (compare Fig 1)

RELATIONS OF ESOPHAGUS TRACHEA AND BRONCHI TO THE HEART AND GREAT VESSELS

The general direction of the esophagus* is vertical, but there are a number of curves in its course At first it lies in the mid line, directly behind the trachea it then inclines somewhat to the left until it reaches

* The esophagus is visualized by having the patient swallow a teaspoonful or more of a thick suspension of barium sulfate in water or some flavored vehicle (Evans [8] uses marmalade)

the aortic arch which causes its displacement again to the mid line thus producing the first curve or aortic impression Because of the left posterior course of the aortic arch the esophagus is deviated to the right and posteriorly and best seen in the anteroposterior right oblique and lateral views (Figs 1 2 and 4) The second curve directly below the aortic impression is produced by pressure of the left bronchus[8] and is easily visible in the right oblique and lateral views (Figs 2 and 4) This deviation is more directly posterior than that of the aortic impression but is also directed somewhat to the right The left bronchus impression has been frequently and erroneously referred to as the pulmonary artery impression but more careful study such as Evans reveals that the pulmonary artery is more anteriorly placed and nowhere in contact with the esophagus The error has been due doubtless to failure to consider the effect of parallax in oblique views The third curve is due to contact of the esophagus with the left auricle and is normally not so well marked as the first two impressions It is directed posteriorly The normal left ventricle usually does not cause any impression Just above the diaphragm the esophagus deviates to the left and is occasionally pressed upon posteriorly by the descending aorta which at this level occupies the median line the two structures thus crossing each other obliquely causing the fourth or descending aorta impression

In a recent study of the cardiovascular relations of the esophagus Evans[8] has emphasized the value of its visualization in facilitating more accurate diagnoses of cardiovascular disease The chief conditions in which it is diagnostically helpful are mitral stenosis aortic dilatation and tortuosity aneurysm and congenital anomalies of the aorta such as dextroposition transposition right aortic arch coarctation

The trachea is at first centrally placed but soon after it enters the superior aperture of the chest it inclines slightly to the right to lie posterior to the beginning of the transverse portion of the arch of the aorta (Fig 1) It bifurcates on the right of the mid line at the level of the lower border of the aortic arch the division being frequently visible in the aortic window which owes much of its lucency to the tracheal bifurcation (Fig 3) The shorter right bronchus continues the general course of the trachea and lies posterior to the right pulmonary artery The longer left bronchus takes a more oblique course After passing in front of the esophagus it lies behind the left pulmonary artery

INDIVIDUAL CHAMBERS AND VESSELS

(a) Superior Vena Cava: This vessel is best seen in the anteroposterior position (Fig. 1) and forms the right border of the cardiac pedicle. Its density is less than that of the rest of the cardiovascular shadow. The pulsation of the cava is slight and complex, as it transmits pressure changes from the right auricle and pulsations and movements of the contiguous aorta and heart as a whole. It becomes dilated from the same causes that give rise to right auricular enlargement (see below) and also from pressure of aortic aneurysm, mediastinal neoplasms, adhesions, etc [9] Increased pulsation may result from tricuspid lesions, and the transmission of the increased pulsation of aortic regurgitation.

(b) Right Auricle: This chamber forms the right border of the cardiac silhouette in the anteroposterior view Its appendage embraces the first portion of the ascending aorta (Figs. 1 and 2) and forms part of the right border in the left oblique view (Fig. 3). It is most likely to be enlarged in right heart failure, auricular fibrillation, tricuspid lesions, beriberi, and certain congenital anomalies (such as auricular and ventricular septal defects, pulmonary stenosis, patent ductus arteriosus) Enlargement of the right ventricle and at times of the left ventricle may displace the right auricle and give the impression of its enlargement Also aneurysm of the root of the aorta or marked tortuosity of the descending aorta may produce an overlapping shadow and suggest enlargement of the right auricle.[10] The pulsation may be increased in tricuspid lesions and atrioseptal defect.

(c) Right Ventricle: This chamber forms most of the anterior surface of the heart and does not normally contribute to the border of the silhouette in the anteroposterior view (Fig 1). To study its contour, the patient must be rotated in the right and left oblique and lateral positions (Figs. 2, 3, 4). Its conus arteriosus or pulmonic conus may be best visualized in the right oblique (Fig. 2) and lateral views (Fig. 4) The conditions which may cause right ventricular enlargement are mitral stenosis, a double mitral lesion, emphysema, chronic pulmonary disease such as pneumoconiosis, certain congenital lesions (such as pulmonic stenosis, auricular and ventricular septal defect, patent ductus arteriosus, *and transposition of the vessels*), acquired pulmonic valvular lesions, pulmonary arteriolar disease, and beriberi. Perhaps the most frequent cause of right ventricular enlargement is right sided failure, which may result

from the lesions above mentioned, or more commonly as a result of left sided failure [11] The right ventricle may show an increased pulsation in acquired pulmonary regurgitation and congenital septal defects

(d) **Pulmonary Artery**· The views which permit the best visualization of this vessel are the anteroposterior and slight right oblique In greater right oblique rotation, at about 45 degrees the cross section of the pulmonary artery is frequently visible as a rounded or oval density within the shadow of the ascending aorta (Fig 2) Occasionally the vessel may be more or less discernible in the left oblique view as it crosses below the aortic window (Fig 3) Dilatation occurs in mitral stenosis, thyrotoxicosis [12] congenital defects (such as patent ductus arteriosus, septal defects and some cases of pulmonic stenosis with poststenotic dilatation) pulmonary arteriosclerosis and arteriolar disease, congestive failure, chronic pulmonary disease (some cases), aneurysm of the pulmonary artery, acquired pulmonic regurgitation and late pregnancy (some cases) Enlargement in the pulmonary artery region, particularly as viewed in the anteroposterior and right oblique positions, may be due to aneurysm of the ascending aorta on its left lateral aspect [10] Increased size of the branches of the pulmonary artery (best visualized are the branches of the right pulmonary artery in the right hilum) may also occur in these conditions The pulsation of the pulmonary artery and its branches is usually increased in certain congenital defects (patent ductus arteriosus and septal defects), thyrotoxicosis, acquired pulmonic regurgitation, cases of mitral stenosis with relative pulmonic regurgitation (Graham Steele murmur), complete heart block [13] late pregnancy and severe anemias

(e) **Left Auricle** With the exception of its appendicular portion, the left auricle lies entirely posteriorly and more cephalad than any other chamber of the heart Minor degrees of enlargement are directed posteriorly and may be visualized in the right oblique and lateral views, especially with the aid of esophagus visualization In the anteroposterior view the esophagus is deviated to the right rarely to the left, by the enlarged auricle With progressively greater enlargement, the left auricle is almost invariably directed to the right so that its border may be seen either within the shadow of the right auricle or it may overlap the right border of the heart to form an additional middle convexity in the anteroposterior view Rarely the left auricle may undergo aneurysmal dilatation and project into the right lung field to reach, at times, the right

chest wall Enlargement of the left auricle occurs in mitral stenosis con gestive failure and auricular fibrillation Less commonly, mitral regurgitation may cause minor degrees of left auricular enlargement with increased pulsation A rare cause of enlargement is acute auricular myocarditis

(f) Left Ventricle The contour of this chamber is visible in the anteroposterior left oblique and lateral views (Figs 1 3 4) Enlargement is directed laterally and posteriorly but is best appreciated in the anteroposterior view and is indicated by greater convexity and length of the left lower border Increase in *size* of the left *ventricle occurs* commonly in hypertension aortic regurgitation congestive failure and aortic stenosis Less frequent causes of enlargement are congenital defects (patent ductus arteriosus coarctation of the aorta ventricular septal defect bicuspid aortic valve and aortic stenosis) coronary disease arterovenous aneurysm and mitral regurgitation Generalized left ventricular enlargement may result from a single large myocardial infarct or from a number of consecutive smaller infarcts A single infarct may cause a localized bulge in the ventricular wall known as cardiac aneurysm The greatest degrees of left ventricular enlargement are seen in aortic regurgitation The pulsation of the left ventricle is ordinarily increased in aortic regurgitation thyrotoxicosis high-grade block and complete block

(g) Aorta The normal tortuosity of the aorta requires rotation of *the patient in all of the four standard positions for its careful study* However any one or a combination of several of the positions may be optimum in the individual case depending upon the pathology present and its localization The arch of the aorta normally takes an irregular spiral course ascending to the right anteriorly and then transversely to the left posteriorly finally turning back slightly to the right to lie upon the left side of the spine The descending thoracic aorta gradually curves *to the right until* at the level of the twelfth thoracic and first lumbar vertebrae it lies in the median line The trajectory of the arch rarely lies in one plane 14 its height and breadth normally depend on the length of the chest and height of the diaphragm The entire course of the aortic arch may be more or less visualized in the left oblique position *but under normal conditions the transverse portion is rendered trans* parent by the trachea which lies posterior to it (Fig 3) In this position

the first part of the descending aorta may be discernible by its pulsation within the spinal shadow, if the eyes are well accommodated and the fluoroscopic field is narrowed Pathologically, the aorta may be altered in length, caliber, tortuosity, density and pulsation, and congenitally, in its origin and caliber The conditions which may cause visible aortic changes are syphilis, atheroma, hypertension, aortic regurgitation and dissection the important congenital defects are coarctation dextroposition trans position of the vessels and right sided arch The density of the aorta depends on its diameter and the structure of the wall and can only be roughly estimated, it should be studied preferably in the left oblique position to prevent superimposition [15] Increased pulsation occurs in aortic regurgitation thyrotoxicosis, severe anemias and in some patients with hypertension

(h) **Enlargement of the Heart as a Whole** This may occur in congestive heart failure bradycardia high grade and complete block, thyrotoxicosis myxedema rheumatic carditis severe anemias, arterio venous aneurysm, and rarely in syphilis and from unknown causes

CALCIFICATIONS

Deposits of calcium may occur in any of the structures of the heart pericardium myocardium endocardium valves, annuli fibrosi, coronary arteries veins aorta and pulmonary artery

Pericardial calcifications have no characteristic shape They may occur in plaques bands and a variety of configurations and may range from mere spicules to almost complete encasement. Pericardial localization is ascertained by rotating the patient behind the fluoroscopic screen when it may be noted that in one view the deposit is at the periphery of the heart shadow and that its movement is that of the adjacent cardiac contour in that view

Myocardial calcification occurs most commonly in infarcted areas but unless cardiac aneurysm is present its differentiation from pericardial calcification cannot be made during life with any certainty

Endocardial calcification is rare and cannot be precisely localized by roentgen examination

Valvular calcification occurs much more frequently than is appreci ated The diagnosis can frequently be made without much difficulty if

its possibility is kept in mind,* if the eyes are properly adapted and a small fluoroscopic aperture is focused on the valvular areas. The common sites are the mitral and aortic valves, their frequency being about equal.[16] Localization within the valves is indicated by the presence of a variable number of small, usually discrete, dense masses, occurring in a small area, deeply placed within the heart shadow in all angles of rotation and by their characteristic dancing movement, directed mainly toward the apex during systole and away from it during diastole.[17] A slight right oblique view has been suggested[13, 18] as the optimum for visualization, but in the author's experience, the left lateral view is preferable, particularly if the attempt is made to determine which valve is involved. The right oblique position is apt to cause greater superimposition of the mitral and aortic valve areas. In the lateral view, the mitral valve position is in the posterior third of the cardiac shadow, and the aortic valve is in the middle third. Both valves are placed approximately in the zone *between the upper and middle thirds of the heart shadow, the level of* this zone varying with localized enlargements of the chambers. The anteroposterior view is also helpful in the differentiation, as the aortic valve is usually lost in the spinal shadow, while the mitral valve is well to the left of the spine, nearer the left heart border.

Calcareous deposits in the annuli fibrosi may be recognized by the presence of a rather uniform dense band in elliptic arrangement,† ranging in length, in different cases, from a small arc to a completely closed curve. These deposits are in the auriculoventricular septum at the base of the valves, the mitral and aortic annuli being the usual sites. Their position within the heart shadow, optimal angles for visualization, and their movement with the heartbeat are all similar to those of the valves except that their motion is apt to be less extensive.

Coronary artery calcification may occasionally be seen. Its roentgen characteristics are superficial position and linear or vermiform distribution. Rarely, the shadows may appear as a double line.[19] Because of its position, it is to be differentiated from pericardial calcification, but the latter is rarely linear. The arteries usually visualized are the anterior descending and circumflex branches of the left coronary artery. A slight right oblique position is optimum for visualization. These linear densities

* Particularly if a loud, rough systolic murmur is heard at the apex or aortic area.

† Actually in circular arrangement, but because of the inclination of the auriculoventricular septum, the annuli appear foreshortened and elliptical.

may be seen on the upper part of the heart shadow, near or on the left border (anterior descending ramus), or obliquely across the cardiac shadow from the upper left border to the lower right border (circumflex branch). Their motion with the heartbeat is slight, the anterior descending ramus density moving with the contiguous heart border, the circumflex moving with the auriculoventricular septum toward the apex during systole and returning with diastole.

Calcified deposits in the aortic wall occur as spicules or curved plaques and are seen most commonly in the region of the aortic knob, best viewed in the anteroposterior position. They also occur not infrequently in the wall of aortic aneurysms. Pulmonary artery calcification is less frequent and is differentiated from aortic calcification by its position.

CARDIAC CONFIGURATION

The normal heart ranges in shape between a paraboloid and an ellipsoid, but the difference in the configuration of the silhouette in different individuals is principally due to various inclinations of the long axis of the heart, which in turn are related to the shape of the chest. The range is between the vertically and almost centrally placed heart in the tall, thin person and the horizontal heart in the short, thick individual. In the average normal heart, the inclination is such that the extension of the silhouette in the anteroposterior view is twice as much to the left as to the right of the mid line of the chest. Shallow chest, funnel breast and right scoliosis usually cause displacement of the heart to the left* with changes in shape. The factor of cardiac position must always be considered when conclusions are drawn concerning configuration, both in the presence and absence of abnormality. For example, it is a not infrequent error to report a mitral stenotic configuration in the vertically placed normal heart and a left ventricular enlargement in the transversely placed normal heart. Conversely, left auricular enlargement may be overlooked in the transverse heart and left ventricular enlargement in the vertical heart. Similarly, with respect to the cardiac pedicle, the wide flare (unfolding, uncoiling) of a normal aortic arch in the short, thick person may lead to an erroneous diagnosis of aortic pathology, and conversely, aortic dilatation may be overlooked in the tall, narrow arch of the asthenic individual.

* Left lateral displacement frequently gives a false impression of enlargement on percussion.

Despite these apparent difficulties the view that reliance should not be placed upon so-called characteristic configurations[20] appears to be unjustifiably extreme The opposite extreme view that the radiologist *can make an etiological diagnosis on the basis of the shape of the heart* alone is also unjustified The roentgen examination is only one of the links in the chain that supports the diagnosis Unfortunately the term *characteristic configuration has reference only to the anteroposterior* appearance of the heart shadow If however in addition to the frontal view the patient be studied in the oblique and lateral views particularly *with the aid of esophagus visualization and study of the pulsatory ex* cursions it will be seen that a small number of uncomplicated conditions present characteristic roentgen appearances while others are only sug gestive *In this connection it should be remembered that the severity* and duration of the pathological changes are of paramount importance as slight and early lesions usually do not cause deformity of the heart shadow Furthermore the presence of combined lesions is associated with deformities of the silhouette in proportion to the relative severity and duration of each of them

The consideration of conditions causing changes in cardiovascular configuration may be roughly divided into the intrinsic and extrinsic causes The intrinsic conditions include acquired valvular disease athe roma syphilis dissecting aneurysm diseases of the pericardium congeni tal heart defects coronary diseases and its sequellae The extrinsic causes include hypertension thyrotoxicosis myxedema emphysema extensive pulmonary fibrosis vitamin B deficiency chronic anemias arteriovenous aneurysm

VALVULAR DISEASE

Mitral stenosis almost invariably presents a characteristic appearance Its chief distinguishing features are enlargement of the left auricle and straightening of the left border (so-called mitralization or mitral con figuration) In the anteroposterior view the normal concavity (waist) of the left border is filled out by the enlarged pulmonary artery and left auricle the aortic knob is less prominent probably due to actual diminution in aortic caliber because of reduced left ventricular output counterclockwise rotation of the heart induced by right ventricular en largement and to obscuring of the normal lower border of the knob by the enlarged pulmonary artery The change in the aortic configuration is

demonstrable by the shallowness or absence of the aortic impression on the esophagus in the anteroposterior view. The normal convexity of the left cardiac border is diminished probably because of rotation of the heart or actual left ventricular atrophy from inadequate filling, or both. The barium meal is frequently impeded and compressed by the enlarged left auricle, and the esophagus is deviated to the right (rarely to the left). The left auricular enlargement is best appreciated in the right oblique and lateral views. In the right oblique view, the depth of the heart from the left auricular impression to the pulmonic conus is markedly increased, because of enlargement in both directions[8] Additional observations are the lengthened and more prominent lower right border in the anteroposterior view; evidences of right ventricular enlargement (including the pulmonic conus) in the oblique and lateral views; filling of the aortic window by the dilatation and elevation of the pulmonary artery (left oblique view); elevation and compression of the left bronchus by the enlarged left auricle or the engorged pulmonary veins[21] or both, increased hilus shadows due to the dilated pulmonary artery branches,[22] clouding of the lung fields due to pulmonary congestion and possibly, in long standing cases, to pulmonary arteriolar sclerosis from lesser circuit hypertension.[23] Greater enlargements of the left auricle and aneurysmal dilatation have been referred to above (page 696). Occasionally the mitral configuration is simulated by a vertically placed normal heart, the heart in thyrotoxicosis and by any condition associated with pulmonary artery dilatation, but in these, the left auricular enlargement and clouding of the lung fields are absent.

Mitral regurgitation, as an isolated lesion, is said to be rare[24] but this has been denied.[25] Clinically, the occurrence of only a loud apical systolic murmur with typical axillary reference in individuals with a definite rheumatic history is not infrequent. However, such patients do not present a characteristic roentgen appearance of the heart. It may be normal in size and shape but occasionally slight left ventricular enlargement is present.

Mitral stenosis and regurgitation are frequently combined and present rather characteristic changes in the silhouette, left ventricular enlargement and greater right ventricular enlargement being added to the features of mitral stenosis. The left border is "mitralized" and the heart is enlarged bilaterally, resulting in a triangular shape. Robb and Stein-

berg[21] have contributed the following observations in this combined lesion: In the frontal view, the right ventricle is broadened and forms three-fifths of the diaphragmatic contour; the pulmonic conus is dilated and lies farther to the left than normally, but it does not enter into the formation of the pulmonic arc in the frontal view, the main stem of the pulmonary artery is dilated but not lengthened and it alone forms the pulmonic arc in the frontal view; the superior vena cava, right auricle and aorta remain normal in the absence of failure.

Aortic regurgitation, when isolated and well advanced, presents certain distinguishing features. The lower left border is increased in length and convexity due to left ventricular enlargement, the aortic knob is exaggerated due to dynamic aortic dilatation; the pulsation of the aorta and left ventricle is increased in extent and is quick and not sustained. Aortic stenosis causes a similar enlargement of the left ventricle, but the aorta is not dilated and its pulsation is either normal or diminished in extent and rapidity.

The combination of aortic and mitral disease produces a configuration somewhat similar to the combined mitral lesion, except that left ventricular enlargement is usually more marked and the pulsatory phenomena of aortic regurgitation are manifest.

Tricuspid valve lesions are rarely isolated. Relative tricuspid regurgitation occurs not infrequently in association with advanced and long standing mitral stenosis and is to be suspected fluoroscopically when the right auricle is unusually prominent and an outward pulsation of its border and of the superior vena cava occurs during ventricular systole Tricuspid stenosis is very rare, its roentgen features being considerable enlargement of the right auricle and, if normal sinus rhythm be present, a marked auriculosystolic pulsation of the superior vena cava. A similar hepatic pulsation may be observed at the right diaphragm during a suspended breath.

Acquired pulmonic valve lesions are also rare. In two observed cases of isolated pulmonic regurgitation (one as a result of pneumococcus pneumonia, the other presumably gonococcal in origin), the pulmonary artery and its branches were moderately dilated and their pulsation was increased; the right ventricle was enlarged, as indicated by greater bilateral diaphragmatic breadth of the heart and greater convexity of the right ventricular borders in the oblique and lateral views.

Aortic disease, if sufficiently advanced, presents characteristic appearances. The study of the relations of the barium filled esophagus is especially valuable in its diagnosis.

(*a*) Atheroma is distinguished by increased length, tortuosity, dilatation, increased density and calcareous deposits. These features may be present in various degrees and combinations or be visible in only one portion. The aortic knob tends to be more prominent, and may be elevated. The aortic pulsation may be diminished while the left ventricular pulse remains normal,[10] particularly if the aorta is dilated. Tortuosity of the descending thoracic aorta at the left auricular level may so displace the visualized esophagus as to lead to an erroneous impression of left auricular enlargement, particularly in the lateral view.

(*b*) Luetic aortitis can be diagnosed only if dilatation is present, particularly in the absence of cardiac enlargement. The dilatation may involve a large part of the aorta, or it may be quite localized. Frequently both generalized dilatation and aneurysm may be present. A luetic origin of aortic regurgitation is suggested only when the aorta, and particularly its root or ascending portion, is abnormally dilated or aneurysmal. In aneurysm of the ascendens the aorta overlaps the superior vena cava *and extends beyond the border of the right auricle below, uncom*monly it may project far into the right lung field. In rare instances of aneurysm of the left posterior sinus of Valsalva, the mass may bulge to the left, displace the pulmonary artery and extend beyond the middle left border. Aneurysm of the transverse portion is indicated by abnormal width of the upper part of the supracardiac shadow. The aortic knob is not infrequently the site of abnormal dilatation. These first three localizations are well seen in the frontal view. Descending aorta aneurysms are best appreciated in the left oblique view but may be also visualized by deviation of the esophagus in the anteroposterior view.[8] In the differential diagnosis of luetic aortic disease, atheroma offers little difficulty if the age of the patient and the presence of aneurysm are considered; furthermore, the ascending aorta is the most frequent site of luetic dilatation, whereas atheroma is only rarely visualized there. The differentiation of mediastinal tumor from aneurysm occasionally presents some difficulty. However, tumors are usually less dense and may lack homogeneity; their margins may be lobulated or lack the smooth oval or circular *contour of an aneurysm; rotation of the patient may reveal*

in one view, absence of continuity with the aortic wall, aside from the portion questionably involved, the aorta is usually normal The expansile pulsation of an aneurysm, when present, is an important differential sign, but unfortunately, it is only infrequently detectible The usual aneurysmal pulsation is a transmitted one and tumors cannot be distinguished on this basis,[15] as they usually transmit the pulsation from contiguous cardiac or vascular structures In difficult cases, the technic of Robb and Steinberg[21] (see below) may be decisive

(c) Dissecting aneurysm refers to the development of a circulation pathway between the layers of the vessel wall in which blood circulates [26] It is a rare lesion and the correct ante mortem diagnosis has been made in only a few instances The roentgen picture varies in different cases depending upon its location and the subsequent pathological changes produced by it Its origin is usually in the ascending aorta, but visible deformity is best appreciated in the arch and beginning of the descendens Suggestive findings are deformity of the supracardiac shadow associated occasionally with an abnormal shadow produced by the dissection along the large branches of the arch, coincident pleural effusion, particularly on the left side, displacement of the esophagus or trachea and cardiac enlargement The possibility of this lesion should be considered in the roentgen examination of patients beyond 40 years of age, particularly with arteriosclerotic and hypertensive cardiovascular disease, who have survived an attack of severe, sudden pain in the chest with shock

DISEASES OF THE PERICARDIUM

(a) Pericarditis without effusion cannot be definitely determined by roentgen examination

(b) Pericardial Effusion The minimum amount of free fluid necessary to give positive x ray evidence has been variously estimated between 250 and 500 cc Small effusions may cause bulging of the posterior inferior reflection of the pericardium to the diaphragm, best seen with the patient standing in the lateral position during sustained inspiration [27] Massive effusions present a distinctive appearance, suggesting a leather water bottle resting on the diaphragm, the characteristic features being sagging at the sides, with usually acute cardiodiaphragmatic angles Comparison in the erect and recumbent postures may reveal marked changes in breadth and configuration due to fluid displacement,[28, 29] unless the

fluid be encapsulated, as in tuberculous pericarditis. The pulsation of the borders is usually slight, wavelike and continuous, the normally different and asychronous auricular and ventricular pulsations being indistinguishable.[29] If the configuration suggests a large pericardial effusion, the maintenance of a normal aortic pulsation with diminished pulsation along the left lower border may be confirmatory.[30] Marked change in configuration and reduction in size of the silhouette in a short time are also suggestive.[31] It has been claimed[32] to be impossible to visualize the heart shadow within the pericardial sac (double contour) because of the equal density of the heart and pericardial fluid.

(c) **Pericardial Adhesions:** Adhesions within the pericardial sac vary considerably in extent and usually give no roentgen evidence of their presence. Occasionally, however, pericardial calcification and exaggerated systolic tractions of the diaphragm may be seen. If the process also invades the mediastinum, certain additional distinctive roentgen signs may become manifest, depending upon the extent and duration of the adhesions. In its advanced and chronic state, known as chronic adhesive or constrictive pericardomediastinitis, the heart is compressed; it is either normal in size or typically small; the pulsations are slight or absent, *("the small, quiet heart"); the contours are apt to be indistinct; the* heart moves little or not at all with respiration and inclined positions of the thorax; in the lateral view, anterior adhesions to the sternum and ribs may be visualized; the superior vena cava may be dilated due to the constrictive adhesions.

CONGENITAL HEART DEFECTS

These usually occur in various combinations[33] so that complete, characteristic roentgen appearances cannot be described. However, the x-ray examination yields positive findings in 85 per cent of cases, and is of diagnostic value in 51 per cent.[34] Certain of the commoner defects may occur either as isolated or primary lesions and give distinctive or suggestive x ray signs.

Coarctation of the aorta of the adult type presents definite x ray evidence. *The isthmus* occurs at or *slightly distal to the origin of the* left subclavian artery; the aortic knob in the anteroposterior view and the descending aorta in the left oblique view are usually absent; the ascending aorta is frequently dilated and its pulsation is increased:

the left ventricle is usually enlarged the enlarged intercostal arteries acting as collateral circulation cause visible erosion (scalloping) of the lower borders of some of the ribs posteriorly

Dextrocardia gives an obviously characteristic appearance

The right aortic arch is distinctive and offers little difficulty particularly with the aid of barium visualization of the esophagus The aortic knob is directed to the right and the esophagus is deviated to the left

Primary congenital hypertrophy (von Gierke s glycogen storage?) *is seen only in infants and young children (maximum recorded duration* of life four years[33]) and presents the picture of considerable generalized cardiac enlargement

Patent ductus arteriosus Because of the aortopulmonary artery shunt this lesion causes increased pressure in the pulmonary artery and its branches which undergo dilatation if the communication is sufficiently large The prominent convexity of the pulmonic arc associated with *increased pulsation of the vessel and its branches are suggestive findings* The heart is either normal in size or shows slight generalized enlargement

Tetralogy of Fallot which consists of pulmonary stenosis septal defect dextroposition of the aorta and hypertrophy of the right ventricle frequently *presents the suggestive wooden shoe configuration (coeur en* sabot) with a double apex one being the elevated left ventricular apex the lower one at the diaphragm belonging to the right ventricle The *central origin of the aorta may be indicated* by *absence of the ascending* aortic contour small or absent aortic knob and shallow or absent aortic impression on the barium filled esophagus [20]

Atrioseptal defect with a large communication at the upper part of the septum causes a large globular heart due to marked right sided enlargement considerable dilatation and increased pulsation of the pulmonary artery and its branches hypoplastic aorta *with diminished or* absent aortic knob [35]

Ventricular septal defect does not cause a distinctive x ray appearance the heart being either normal in size and shape or slightly enlarged bilaterally with right ventricular preponderance

Aortic stenosis and bicuspid aortic valve cause generalized cardiac enlargement with left ventricular preponderance *Aortic stenosis is usually associated with a hypoplastic aorta*

CORONARY DISEASE AND ITS SEQUELAE

It is uncertain whether coronary arteriosclerosis, *per se*, can cause cardiac enlargement. Excluding hypertension, abnormal rhythms such as auricular fibrillation and heart block, previous myocardial infarction and other possible causes of enlargement, the vast majority of patients with a typical history of effort angina pectoris have normal-sized hearts Occasionally, however, patients are observed in whom no other cause for enlargement can be found.

Coronary Occlusion: A number of patients were examined fluoroscopically, within a few days of the attack.* The majority showed no abnormality in size or shape of the heart. In the remainder slight cardiac enlargement, mainly left ventricular was observed. Other causes of enlargement were satisfactorily eliminated. The position of the infarct (as determined by the electrocardiogram) and the presence of mild left heart failure (basal râles and roentgen evidence of pulmonary congestion) appeared to be the important factors involved in the enlargement. (The size of the infarct must also play an important rôle, but this could be only surmised) Anterior infarctions were more commonly associated with enlargement than posterior infarctions, but in several of the latter, abnormal rhythms (heart block and auricular fibrillation) were probably influential in the increased size. The pulsation was reduced in amplitude in most of the patients examined. A few of those who had shown enlargements were reexamined after recovery from the attack and in these the heart had returned to normal size and shape.

Cardiac Aneurysm: This usually late sequel of myocardial infarction can be accurately diagnosed only if an abnormal bulge is visualized on the left ventricular border. Its site is usually near the apex. Pulsation of the mass is usually diminished and it generally moves with the contiguous ventricular border, although the reverse movement has been described.[13] Calcareous deposit in the wall of the aneurysm occurs occasionally.

EXTRINSIC CAUSES OF CARDIAC ENLARGEMENT

Hypertension: The roentgen appearance is not always distinctive. The left ventricle is usually enlarged; the aorta may be normal in diameter or slightly and uniformly dilated. The pulsation of the aorta

* Before the electrocardiogram was reported, the nature of the attack having been doubted by the referring physicians Unpublished observations

is usually within normal limits, but may be slightly increased, particularly in those patients with very wide pulse pressures. The left ventricular pulsation is usually normal and in marked enlargements may be actually diminished. The pulsations in hypertension rarely attain the magnitude of those in aortic regurgitation. The rapidity of development of left ventricular enlargement varies considerably in different patients, depending upon the degree and duration of the hypertension, and the associated vascular changes. In relatively benign cases, the enlargement may be so retarded that years may pass before it becomes appreciable. In the malignant type with widespread arteriolar necroses, enlargement may occur within a few weeks.

Other Causes: Emphysema, extensive pulmonary fibrosis, of which pneumoconiosis is an example, and pulmonary arteriolar disease are usually associated with varying degrees of right sided enlargement. In emphysema, the hypertrophy is not ordinarily appreciated because of the low position of the diaphragm and the usually vertically placed heart. However, additional observation in the oblique and lateral views may reveal greater than average depth of the heart tending to a globular conformation, increased prominence of the pulmonic conus and right ventricular borders and dilatation of the pulmonary artery and its branches.

Thyrotoxicosis, myxedema, severe and chronic anemias, arteriovenous communication and vitamin B_1 deficiency may cause enlargement of the heart shadow. Uncomplicated thyrotoxicosis causes a significant generalized increase in heart size in approximately 26 per cent of cases, 51 per cent of patients show increased prominence and/or pulsation of the pulmonary artery,[12] the ventricular pulsation is apt to be characteristically quick,[12, 36] the lungs are frequently abnormally transparent. In myxedema, slight and occasionally marked generalized enlargement occurs in approximately 20 per cent of cases: the cardiac and vascular pulsations are distinctively diminished and sluggish. Severe anemias of various types may present a cardiac roentgen picture similar to thyrotoxicosis because of slight generalized enlargement and increased pulsation, but the prominence of the pulmonary artery and the peculiar, quick pulsation are usually absent. Arteriovenous communication, depending on its extent and duration, is frequently associated with cardiac enlargement without other special features. Vitamin B_1 deficiency usually causes a

predominantly right sided enlargement. The advanced cardiac manifestations of beriberi are rarely seen in this country except in occasional instances of prolonged alcoholism, but the possibility of milder degrees of this condition should be considered in otherwise inexplicable cardiac enlargement.[37] In this special group of five conditions, the cardiac and pulsatory abnormalities tend to disappear with improvement or cure.

SPECIAL X-RAY METHODS

1. Roentgenkymography: This was first used by Sabat[38] in 1911. This method records the movements of the borders of the cardiovascular shadow. In its simplest form, a large lead sheet with a single, long, narrow horizontal slit (0.4 mm wide) is placed between the patient and the film, with the slit at the level of the cardiovascular shadow where it is planned to record the border movements; the central beam of the x-ray tube is directed perpendicularly at the heart border on the same level, the tube, patient and slit being fixed in position; the film-loaded casette is then moved past the slit at a uniform speed, the patient holding his breath during the exposure. The most widely used modification of this original method is the multiple-slit kymograph, with parallel equidistant slits of sufficient number and length to include the entire cardiovascular silhouette; the distance between the slits is usually 10 to 12 mm., the travel of the film being slightly less to prevent overlapping of the adjacent exposures; the duration of the exposure is timed to include at least one complete heart cycle. Good contrast between the edge of the cardiovascular shadow and the continguous lung field is obviously necessary. The result obtained is a wavelike shadow (single slit) or a series of shadows (multiple slit) which are commonly supposed to represent the pulsation at the points recorded. It should be emphasized that the movements of the heart are quite complex and include not only contraction and distention, but also total displacement, spiral torsion and simple rotation; these movements do not all occur in the same plane nor in the same directions; furthermore, they differ in time and individual contribution in different parts of the heart and great vessels; at any given point, they may be mutually additive or neutralizing in various combinations; they differ in different individuals depending upon the size, shape and position of the heart; the film record represents at any moment the projection, in the plane of the film and parallel to the slit, of only the

resultant of all the horizontal components of movements in all directions. Despite these criticisms, it must be admitted that the movements due to contraction and distention are probably of greater magnitude than any of the others, but the complexity of the movements makes attempts to evaluate the importance of each of them uncertain in result.[17] This *difficulty is particularly applicable to multiple slit kymograms, in which* the waves are too contracted in the vertical direction to permit analysis without magnification Single-slit kymography permits considerable expansion of the curve and consequently an analysis of time relations (by simultaneously recorded electrocardiograms) that may be applicable to specific problems[12, 17, 39] An analysis of over 200 single slit roentgen kymograms of the left ventricular border near the apex, in normal and diseased hearts, has convinced the writer that it is difficult if not impossible at present to establish standards, because of the wide dissimilarity of the curves However, if the limitations of the method are constantly recalled, its continued use and the correlation of the wave forms with *clinical, electrocardiographic* and necropsy data may, *in the future*, yield unsuspected and valuable information.[40]

2. Visualization of the Chambers of the Heart and the Thoracic Blood Vessels: Robb and Steinberg[21, 41] have recently made this procedure practicable, although it had been attempted previously with failure or only limited success. The method consists in "the rapid peripheral venous injection of a radiopaque solution (70 per cent Diodrast) into the blood stream to make the interior of the heart opaque to the roentgen rays during the first circulation and the making of roentgenograms at the moment of their opacification." It is first necessary to do circulation time studies to ascertain, in the individual patient, the times at which the *pulmonary circulation and the left side of the heart may* be best visualized. "The technic is exacting, requiring dexterity, precision, teamwork and strict adherence to detail " At present writing, *the potentialities of the* method appear to have initiated a new epoch in cardiac roentgenology. It should permit a reevaluation of the anatomic relationships in both normal and pathologic hearts in living subjects, a more accurate interpretation of specific cardiac lesions and congenital defects, differentiation of the vascular or nonvascular nature of abnormal masses in the mediastinum and improved diagnoses of pulmonary lesions The method is apparently safe and practical, but too complicated, at present, for use

in routine roentgenography However, the accumulation of sufficient data by trained observers may make it necessary only in cases presenting unusually difficult diagnostic problems

MEASUREMENTS

1 **Heart** The estimation of relative heart size is one of the most important uses of cardiac roentgenology It has long been known that the size and shape of the heart are related to the size and shape of the chest Original estimations of heart size were, in fact empirically based on this relationship Subsequent to simple inspection many and diverse attempts were made, and are still being made to reduce the correlation to mathematical terms The time honored cardiothoracic ratio is an example, and is still widely used The experience of numerous workers however has shown the normal range to be too wide to be of much value in the individual patient The limits may be normally as low as 35 per cent in vertically placed hearts and as high as 60 per cent in quite transversely placed hearts Furthermore undoubted cardiac enlargement frequently falls well within the upper normal limits of the cardiothoracic ratio Similar objections may be raised to the use of other cardiothoracic relationships such as the angle of disappearance of the apex behind the spine on rotation of the patient [51] the depth of the retrocardiac space,[6] the ratio of the oblique transverse diameter of the heart to the distance between the anterior rib margin and the spine in the left oblique view [56] Recent studies have indicated a better correlation between heart size and body weight and surface,[42 43] although it is claimed that the inclusion of chest diameters with body weight improves the correlation [44]

The methods of cardiac measurements used are the diameters the frontal area and the volume The diameter measurements (transverse long basal and oblique diameters) are still employed by many roentgenologists The frontal area measurement requires the arbitrary completion of the invisible upper and lower borders of the heart This method has gained favor with many workers because of the introduction of convenient tables of prediction [45 46] which in most cases provide a reliable estimate of normal size An objection to this type of measurement is that it fails to take into account the anteroposterior diameter or depth of the heart as determined in the lateral view The depth diameter varies

widely in its relation to the size of the heart in frontal projection;[14] an analysis revealed that it averages 73 per cent of the frontal transverse diameter.[17] The transverse diameter of the heart in the left oblique view (45°) averages 86 per cent of the frontal transverse diameter.* Vertical hearts tend to be deep and transverse hearts shallow, extreme disparity is seen in the compressed disc shaped hearts in very flat chests and funnel breast; pathological deformities due to local enlargements cause variable relationships between frontal size and depth diameter. It should be said however, that if the depth and oblique diameters bear average normal relations to the frontal transverse diameter, the frontal area estimation is probably a reliable criterion of relative cardiac size. These considerations have led to the view, which is generally accepted, that the ideal cardiac measurement is volumetric. Various attempts have been made to determine individual cardiac volume, the most notable of which is plastic reconstruction of the heart from roentgen contours in consecutive rotation,[18] the volume being then determined by water displacement. The technic is feasible, but time consuming and hardly applicable to routine clinical cardiology. The best indications for its use appear to be accurate investigative work and the establishment of criteria and formulae for the prediction of normal heart size.

Based on the supposition that the heart is a regular paraboloid or ellipsoid, or a mean between the two, formulae have been derived from which heart volume may be calculated.[49, 50] The basic formula is $V = A \times D \times K$, in which V is the volume, A is the frontal area in square centimeters, D, the depth of the heart in centimeters and K, the constant. The figures for the constant are 0.59 for a paraboloid and 0.67 for an ellipsoid. The mean, 0.63, is usually employed, but the constant may be varied between the extremes, depending upon the individual cardiac configuration.[42] Calculated volumes compared favorably with actual volumes obtained from plastic reconstructions and orthodiagraphed formalin fixed anatomical specimens. The range of normal volumes obtained by the use of the Rohrer-Kahlstorf formula varied but little with different workers. In terms of heart volume cubic centimeters per kilogram of body weight, the range was 8 to 11 in men and 7 to 11 in women, with an upper normal limit of 11.7;[50] 7 to 13;[43] 6 to 12.[40] In terms of heart volume cubic centimeters per square meter of body

* Unpublished observations

surface, the range was 250 to 490[43] and 200 to 450[42] It is hoped that, perhaps with the aid of the plastic reconstruction method applied to a sufficiently large number of normal individuals, improved formulae may be found from which may be written tables of prediction of approximately normal heart volume based on individual body measurements

2 Aorta The caliber of the normal aorta is dependent mainly on the size of the body and the age of the individual Its normal diameter probably does not exceed 3 5 cm[51] The caliber diminishes rather suddenly below the origin of the left subclavian artery[52] In younger individuals up to 35 years, the ascending aortic diameter is to the descendens as 18 13, in older persons up to 60, as 4 3[53] If the right border of the supracardiac shadow extends beyond the line of the right auricle in the frontal view, the ascending aorta is probably pathologically dilated The measurement, in the anteroposterior view, of the total transverse diameter of the supracardiac shadow as a criterion of aortic dilatation is open to question because of the wide normal range in vertically and transversely placed hearts Reference has already been made to the possibility of overlooking aortic dilatation in a tall narrow arch and erroneously diagnosing disease in a normal short broad arch, if reliance is placed upon this dimension alone The diameter of the ascending aorta cannot be measured roentgenologically with any certainty Attempts to measure the ascendens in the left oblique view are subject to error because of the inclusion of the superior vena cava shadow on one side and the obscuring effect of the right bronchus on the other (Fig 3) The diameter of the transverse portion of the arch may be occasionally measurable in the left oblique view at angles of 45° or more if both the aortic triangle[7] and the aortic window are well visualized (Fig 3)

If the aorta is sufficiently dense as the result of disease the diameters of both the transverse and descending portions may be directly estimated in the left oblique view The aortic impression on the barium filled esophagus may be frequently useful in the measurement of aortic diameter In the anteroposterior view a line is drawn from the deepest point of concavity of the impression to the left edge of the aortic knob the length of this line minus 3 mm for the thickness of the esophagus wall, represents the diameter of the aorta[54] This measurement is subject to error as the left extremity of the line is not always the same portion of the aorta it may be the left side of the ascendens beginning of the

descendens, or at a *point lower on the descendens* [8, 53] When the line is horizontal and not inclined,[53] and particularly, when the aortic knob and aortic impression form a circle and not an oval,[55] the aortic diameter at this point logically appears to be more accurately measurable If the aortic impression in the right oblique view is deep and semicircular in outline, aortic diameter may be estimated from the vertical diameter of the impression [8] but it is necessary in this case to subtract the thickness of the esophagus wall at each end of the line On the basis of these considerations and additions to our knowledge, criteria for estimating normal aortic diameter dependent on age and body size are still awaited

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CHAPTER XXX

DISTURBANCES OF THE HEARTBEAT

By George Herrmann, M.D.

General Considerations: A disorder of the heartbeat is usually one of the first abnormalities to come to the physician's attention in the examination of a patient. The traditional *"entre,"* the accepted primary professional gesture of palpation of the pulse, often yields significant evidence to the trained fingers of the alert examiner. Much valuable information may be elicited in an intelligent study of the pulse even while listening to the patient's complaints, while developing the symptom complex, and while getting the historical past and etiological facts volunteered by the patient. Palpation of the pulse must not be, as it all too often is, merely an expression of friendliness, a reassuring motive, a vestige of the ancient and honorable art of the practice of medicine.

Disturbances in the pulse are dependent upon disorders in the cardiac mechanism or heartbeat. The pioneer work of Mackenzie with the polygraph and the studies of Einthoven and Lewis with the electrocardiographic method of precision have clarified the subject. It has now become one of the most scientifically exact in medical practice. Present knowledge is such that an accurate interpretation of disorders of the pulse and heartbeat at the bedside can be made one of the most precise parts of the physical examination. This fact the writer hopes to be able to demonstrate in the following discussion.

The disturbances or abnormalities of the cardiac mechanism may dominate the clinical picture. Most notoriously those that are of least serious or clinical significance, often give rise, especially in the neurotic patient, to a long train of symptoms. On the other hand, in more stolid individuals, even a severe disturbance may be recognized only as a slightly peculiar fluttering sensation or a slightly unusual throbbing. The effects may be only of a momentary or transient nature, may recur in

paroxysms of shorter or longer duration, or may be absolutely persistent and permanently established.

A localized minute microscopic change in the heart muscle cell may be sufficient to inaugurate a disturbance of the heartbeat. However, the *symptoms that arise in these conditions in general are usually due to the* peripheral sensitiveness or hypersensitiveness of the individual nervous patient.

In some of the severe disorders, however, there is a distinct change in the functional efficiency of the heart as a result of mechanism disturbances and the total blood flow is undoubtedly often seriously interfered with. Under such circumstances, the patient usually complains of the symptoms of myocardial insufficiency, *viz.*, congestive heart failure with dyspnea, orthopnea, or edema and pain, rather than of the sensations *that might be created by the mechanism abnormality.*

The pathological anatomy may, however, be insignificant or rather nondemonstrable, consisting of slight physical or chemical intracellular or intercellular changes which would produce little if any abnormal staining reaction, and consequently may escape even the most careful microscopic study. Then, again, gross or microscopically demonstrable, post mortem, anatomical or histological abnormalities cannot always be held directly responsible for the mechanism disturbance that had been present before the patient's death. Under certain circumstances in which *lesions are present in the primary conduction pathways of the heart, it* is justified to assume a causative relationship.

Direct and primary changes in the vascular bed and circulation of the heart itself are often the basis of damage. This may be localized to minute points but usually the effect is widespread in diffuse areas throughout the myocardium. There may be evidence only of disease in another organ or part of the body. This, however, is known to affect the heart itself and is often the basis of drainage This may be localized also through actual chemical agents.

Interpretation or evaluation of the findings must be made with due regard to a general survey of the cardiovascular system in respect to the pathological physiology of the disease that is found. The mechanism disturbances may be of paramount importance and call for measures directed primarily toward their alleviation. Nevertheless, they cannot be considered as distinctive clinical entities in themselves, but merely as symp-

toms expressing the effect of a disease process on the heart. Such heart disorders may be entirely nervous or may be the result of the general effects that a disease process has had on the vital organ.

Examination of the Pulse and the Heartbeat: The phenomena that may be detected in the peripheral arteries, the radial, brachial, carotid, femoral, and dorsalis pedis, are the direct results of left ventricular activities that have been propagated into the periphery through the arterial system. The examination begins with palpation of the pulse in the radial artery with the arm at the side and with it raised above the level of the heart.

The rate and the rhythm of the pulse beats, also the volume, tension, sustaining power, and, in general, the form of the pulse wave are taken into account. Note whether poorly sustained or well sustained, or bounding, quick, collapsing, or slow plateau, whether it is a dicrotic or an anacrotic pulse. The brachial, but especially the carotid, should also be carefully examined and the apex of the heart simultaneously palpated and auscultated.

The movements in the veins of the neck are often of some significance and should be noted. These waves are usually seen in the jugular bulb region in thin necked individuals and the character of the venous wave is of some significance in the differential diagnosis of mechanism disturbances.

After the examination at rest, the patient's heart should be increased by exercise if he can tolerate it, or by the use of amyl nitrite, nitroglycerin, or atropine. If the rate is primarily high, the effects of carotid sinus pressure should be noted. The general nervous reaction in the patient is of considerable significance in the evaluation of findings, especially in the presence of a rapid pulse.

The examination of the heart should always be carried out with simultaneous palpation of the carotid pulse. In this way, and only in this way, is it absolutely possible to localize and identify the first and second heart sounds, the systolic and diastolic periods of the heartbeat. The disturbances that fail to open the aortic valve are thus detected, for the auscultatory phenomena will be heard over the heart but no accompanying wave will be palpated in the carotid. This dissipation of cardiac energy without any peripheral effect is commonly present in serious arrhythmias.

Cardiac mechanism disturbances can be analyzed and for the most part accurately determined by the ordinary bedside methods that are at the disposal of all practitioners. There are, unfortunately, a few disturbances that defy complete analysis by any other than the electrocardiographic method.

Emphasis will be placed upon the findings on physical examination, inspection, palpation, and auscultation of the activities of the apex and the carotid pulse at rest and under stress. The electrocardiographic method is the *court of last appeal and should be applied as a corroborative* method whenever it is available. Present bedside methods are the fruits of the electrocardiographic method of precision in the hands of experts. Frequent corroboration, checks and tests tend to sharpen the diagnostic acumen of the modern, scientific physician. The polygraphic method has been almost entirely abandoned because of the difficulty and unreliability of the technical procedure. There is much uncertainty in interpretation of the polygram as compared with the simplicity of the electrocardiographic diagnosis.

To establish a diagnosis it may be necessary to repeat the examination after the application of the blood pressure cuff or following exercise or carotid pressure, or the administration of amyl nitrite, nitroglycerin, atropine, adrenalin or pilocarpine. The disturbances and their characteristics may be learned by rote and the diagnoses made by rule of thumb *the general characteristics of the disturbances are sufficient for fairly accurate* interpretation of the results. It is, however, much easier and safer to visualize the mechanism disturbances in terms of the normal and pathological physiology of the origin and propagation of the excitatory impulses over the heart and in terms of the associated mechanical contractions and waves.

Special Anatomy and Physiology of the Heart: It is desirable to review briefly the specialized anatomy and physiology of the heart to insure an adequate conception of the subject when it is presented to those who have not made a particular study of it. In the first place, there are certain structures in the heart that are practically submerged and are not demonstrable in the gross examination of even the large adult human heart. Microscopically, these important structures are seen to consist of rather small, pale, embryoniclike heart muscle cells with some neuro-

muscular tissue and in some areas endings of nerve fibers and ganglion cells lying just beneath the endocardium

The first structure of importance is the sinoauricular node a small mass of tissue about 2 cm long and 2 mm in width It is somewhit comma shaped and is imbedded in the upper part of the sulcus ter

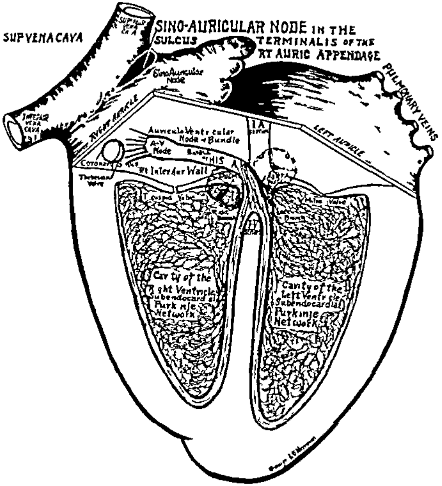

FIGURE 1 \ diagrammatic representation of the special structures that control the origin and conduction of the impulses which regulate the cardiac mechanism

minalis the groove between the junction of the superior vena cava and the right auricular appendage It is sometimes called the Keith Flack node after its discoverers and is found to be made up of striated fibers, containing uniform and well marked elongated nuclei, fascicular in arrangement and imbedded in densely packed connective tissue The cells are smaller than those of ordinary auricular muscle, are richer in glyco-

gen, and are supplied with fibers derived from the vagus and sympathetic nerves This sinoauricular node was quite properly named the *pace maker* by Sir Thomas Lewis

The next structure of importance in this specialized system is the *atrioventricular node located on the right side of the interauricular* septum below and slightly anterior to the opening of the coronary sinus and the Thebesian valve This node of His and Aschoff with fan shaped head is microscopically similar to the Keith Flack node and forms the bulbous beginning of the auriculoventricular bundle From this node there proceeds the auriculoventricular or His bundle a compact ensheathed cord of specialized fibers which runs forward and downward in the right side of the interauricular septum for about 2 cm to form the only conducting bridge between auricular and ventricular tissues *On reaching the membranous portion of the undefended space in the* intraventricular septum it divides and straddles the septum the left portion piercing the membrane divides into three strands and spreading out under the posterior aortic cusp produces the broad flattened left branch of the bundle while the right branch extends without major subdivision to the anterior papillary muscle on the right

The gateway to the ventricle and the path descending from it are sometimes called after the discoverers the Aschoff His Tawara node and bundle but both are more properly called the auriculoventricular node *and bundle The right bundle branch spreads downward on the* intraventricular septum branching profusely as it reaches the bases of the papillary muscles the left bundle branch divides immediately into three sub-branches as it pierces the membranous part of the intraventricular septum and spreads to form subendocardially as a dense syncytial meshwork This specialized tissue extending throughout the ventricular cavities beneath the endocardium constitutes the so-called Purkinje fibers or arborizations It is because of this widespread *anatomical system that* prompt and complete excitation of the ventricular muscle is accomplished and is rarely interrupted by marked subendocardial processes

Some Physiological Considerations The normal physiology of the genesis and propagation of the excitatory impulse is most intriguing although still far from being fully understood A theoretical consideration of the important process must now suffice The cell may be pictured as a minute mass of protoplasm separated from the surrounding tissue

(c) Ventricular (right or left basal or apical).
(d) Unknown origin

4 *Paroxysmal Tachycardia* (Regular)
(a) Auricular
(b) Junctional (nodal or auriculoventricular)
(c) Ventricular (right or left)
(d) Unknown origin

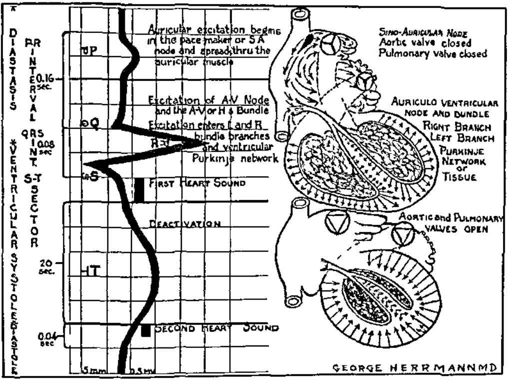

FIGURE 2 (Courtesy C V Mosby Co St Louis Mo)

5 *Auricular Flutter* (Regular)
(a) Paroxysmal
(b) Chronic

6 *Auricular Fibrillation* (Irregular)
(a) Paroxysmal
(b) Chronic

II. DISTURBANCES IN PROPAGATION OR CONDUCTION OF THE IMPULSE

1 *Sinoauricular Heart Block* (Irregular)

2 *Atrioventricular Heart Block*
(a) Partial A V Block
(1) Prolonged A V conduction (Regular)
(2) Occasional dropped beat (Irregular)

fluid by an exceedingly thin membrane On the outer surface of this membrane, positively charged ions are more numerous, while on its inner surface, negatively charged ions are in the majority The attraction between these unlike ions creates an electric stress, but ionic intermingling is prevented by the membrane which is impermeable to them The metabolism of the resting cell supplies the energy required for maintenance of this unstable condition and for its subsequent periodic suspension

In case of the cells of the nodal tissues, this state of dynamic equilibrium is a momentary one Gradually, during diastole, the electric stress increases, or the resistance of the membrane decreases, until abruptly the membrane breaks down and loses its relatively impermeable state Associated with this breakdown, a fall occurs in the electrical potential of the cell surface, and chemical processes are initiated within the cell which lead, on the one hand, to contraction and, on the other hand, to restoration of the impermeable membrane with its electrical double layer Before this restoration has gotten well under way, however a local current begins to flow between the positive, inactive, adjoining cells and the negative, active cell—a current of such intensity that it initiates a breakdown of the surface of the inactive cells and this, in turn, leads to excitation of cells at increasing distance Thus, the excitatory process spreads rapidly and radially from the specialized sinoauricular node or pacemaker and the phenomenon of conduction of the impulse and the associated wave of contraction is observed

Arriving at the auriculoventricular node, the impulse is slowed sufficiently to allow completion of the auricular systole and then passed through the A V bundle to the ventricle Thence it is propagated through the right and left branches and spreads in the Purkinje network at the rate of about 5000 mm per second thence out through the heart muscle cells at one tenth that rate, stimulating in order and almost simultaneously the heart muscle of both ventricles, with, as a result, a concerted bilateral ventricular contraction

A brief rest period or diastole then supervenes and the processes recur at the sinoauricular node This rhythmic formation of impulses in the sinoauricular node takes place at varying rates and, especially under abnormal conditions, other irritable foci may supersede the node and act as pacemakers The impulse spreading through the auricular

muscle is rarely obstructed but, because of the narrowness of the gate way and the bridge, conduction through the A V node and the His bundle may be interrupted by relatively circumscribed, slight or gross cellular changes in these structures The ventricular muscle cells frequently *become hyperirritable and interrupt the regular rhythm* by sudden, persistent discharges from minute abnormal foci in the specialized or non specialized tissue of the free wall musculature Tissues that have been slightly damaged, perhaps by undernutrition or other injuries due to circulatory disturbances or toxic changes from bacterial poison, give rise to abnormal foci Each of these premature ectopic impulses or extrasystoles usually spreads retrogradely and meets and extinguishes the oncoming normal impulse from the S A node thus producing a prolonged postectopic diastolic rest period

Effects of Nervous Control The auricular muscle the sinoauricular node, the auriculoventricular node and perhaps also a larger part of the His bundle, are under the direct control of the cardio inhibitory fibers of the vagus, while the whole heart is under sympathetic influence *The rate of impulse formation is dependent in large measure upon these* nervous influences An increased vagus tone causes a slowing of impulse formation in the pacemaker or lowering of the rate of impulse formation in the sinoauricular node and reduces the heart rate below the normal accepted level of 70 Likewise, a removal of the vagus effect or stimulation of the sympathetic or accelerator nerves produces a rise in rate, speeds up the rate of impulse formation distinctly above the normal level of 85, usually to more than 100 per minute a condition which is spoken *of as a sinus tachycardia* The vagus *tone may fluctuate as a result of* the respiratory waves in the blood pressure which effect a rhythmical waxing and waning of the heart action, a common irregularity the so-called sinus arrhythmia The normal youthful heart action slows with expiration and quickens with inspiration

The presence of disease in other parts of the body affecting directly or indirectly the vagus tone accentuates these effects on the sinoauricular node or the pacemaker This is especially true, as will be detailed presently, of diseases of the thyroid gland *the brain, the general nervous* system the psyche, or the gastrointestinal canal The impulse formation in the sinoauricular node may be entirely suppressed momentarily by extreme vagotonia, producing a sinoauricular standstill or block in rare

instances. Pathological changes in the tissues about the node are quite likely to be necessary for the production of this disturbance. True sino auricular block is, therefore, probably of some significance in adults.

Although the sinoauricular node usually dominates the mechanism as the pacemaker, other foci, in auricular, junctional or ventricular, specialized or unspecialized tissues, occasionally become more labile or irritable as a result of temporary nervous, mechanical, circulatory, nutritional, physical, or chemical changes and give rise to premature discharge of impulses. These then spread in all possible directions, wherever paths are open in the muscle or specialized tissue, and stimulate the heart muscle *cells to premature contractions, recognized as ectopic beats or so-called* extrasystoles. The resulting disturbance of initiation or propagation of the next regularly placed sinus impulse results in the postectopic or so-called postextrasystolic pause.

Under normal conditions, the wave of excitation originating in the sinoauricular node spreads fanwise through the auricular musculature, activating it and then dying out. A circus mechanism (producing auricular fibrillation or flutter) may supersede the pacemaker, as a result of certain auricular myocardial changes. The propagation of the impulse or wave of excitation may be obstructed by disease in the A-V node or in the His bundle or a branch of the His bundle.

CLASSIFICATION OF DISTURBANCES OF THE PHYSIOLOGICAL MECHANISMS OF THE HEARTBEAT

I. IMPULSE INITIATION DISTURBANCES

A. NOMOTOPIC Regular Rhythms *(Homogenetic)*:

1. *Variation in the Vagal and Accelerator Action* (Regular):
   - (*a*) Sinus Tachycardia, abnormally rapid regular sinoauricular rhythm.
   - (*b*) Sinus Bradycardia, abnormally slow regular sinoauricular rhythm.
2. *Vagus Arrhythmias* (Irregular):
   - (*a*) Sinus Arrhythmia, phasic respiratory shift in vagus tone.
   - (*b*) Sinoauricular standstill.

B. ECTOPIC. Irregular Rhythms (Heterogenetic):

3. *Premature Contractions*, rare, frequent, irregularly occurring, regularly recurring, quadrigeminy, trigeminy, bigeminy or *coupling (Irregular):*
   - (*a*) Auricular.
   - (*b*) Junctional (nodal or auriculoventricular).

(*c*) Ventricular (right or left basal or apical)
(*d*) Unknown origin

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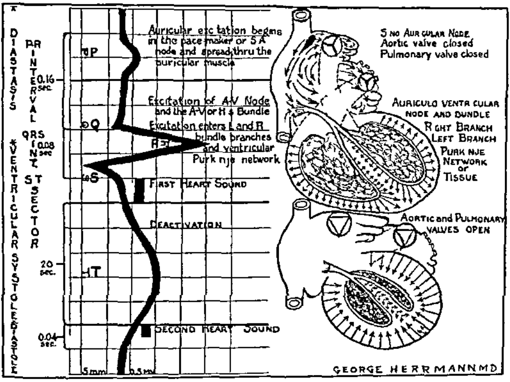

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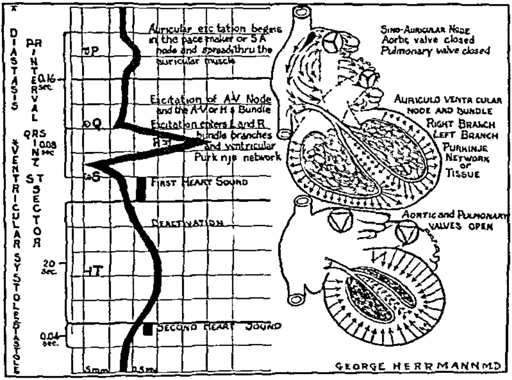

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(2) Occasional dropped beat (Irregular)

(3) Low grade A-V block 10-9 down to 4 3, 2-1, and occasionally to 4-1 and even 6 1.

(*b*) Complete A-V Dissociation (Regular):

(1) Temporary or transient.

(2) Chronic, permanent.

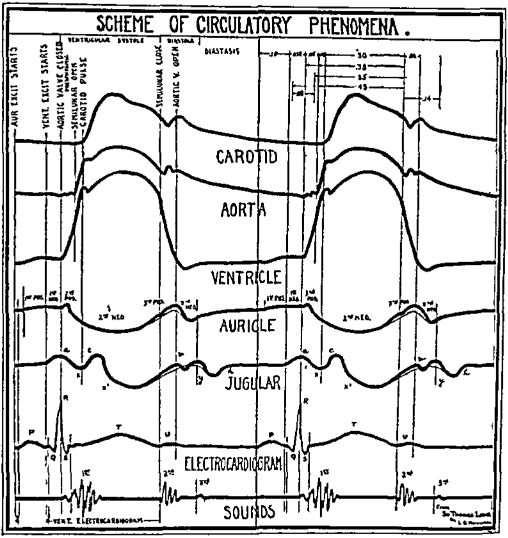


FIGURE 3

3 *Bundle Branch Block* (Regular).

4. *Alternation* (pulsus alternans).

Clinical Types and Differentiation: The clinically recognizable types of disturbance of the cardiac mechanism should be had clearly in mind before beginning the discussion of each of the individual disturbances

It is most logical to classify the conditions on a physiological basis proceeding from the purely functional and definitely innocuous disturbances to those of increasing seriousness or significance and, finally, to those disturbances that in themselves mean heart disease. This classification of the various conditions does not easily lend itself to clinical differential diagnoses. It is therefore desirable to discuss the conditions in the way in which the diagnostic problems may present themselves.

The heartbeat may be fast or slow, regular or irregular, persistently in the same condition or changing from time to time from one condition to another. There are some conditions in which the rate is always fast and others in which it is always slow. Some disturbances vary not one beat in minute to minute counts, others vary greatly in periodic counts; some are always regular, others always irregular; some are usually regular but occasionally irregular, others are usually irregular and occasionally regular. Grouping the disturbances according to these findings is the first step in differential diagnosis. The degree of the disturbance is quite important and this is determined by the careful full minute count of the rate of the heart or apex beat counted with a stethoscope.

Differential Diagnosis. *A rapid regular* heart action may be *sinus tachycardia, paroxysmal tachycardia,* or *auricular flutter.* *A slow regular* mechanism may be *sinus bradycardia* or *auriculoventricular heart block,* either high grade partial or complete. *A rapid irregular* heart action usually means *auricular fibrillation,* but may mean frequent *premature contractions, interrupted short paroxysms* of *tachycardia* or *irregular blocking* in *auricular flutter.* *A slow irregular* mechanism may be a *digitalized auricular fibrillation* or one of the slow fibrillations of aged people, *partial heart block* or a *normal bradycardia* interrupted by *premature contractions* or a *sinus arrhythmia.*

Now to proceed with further differentiation it will be necessary to give some of the diagnostic characteristics of the commoner types of disturbances.

The first and most important rule should be that any *absolutely irregular heart action* that persists when the heart rate is increased to 1[illegible]0 per minute most probably is *auricular fibrillation.* If irregularity persists as the rate rises to 140 it is almost certain that the mechanism disturbance is auricular fibrillation. All other disturbances that produce irregularity disappear as the heart rate rises. The heart rate may be

increased by slight exercise or by the use of amyl nitrite, nitroglycerin or atropine. In the presence of an absolute arrhythmia, a rise in the heart rate to 100, 120 or 140 is not usually accompanied by a similar rise in the pulse rate. Many of the ventricular contractions come at such short diastolic intervals and are consequently so feeble, and act upon such a small volume of blood, that they are not able to raise the blood pressure above that in the aorta. They consequently do not open the valve and, therefore, are not propagated to the periphery, and thus is produced the disturbance known as *pulsus deficit.*

Premature contractions coming early in diastole may also fail to open the aortic valve and, therefore, likewise result in a deficit.

An irregular rhythm due to premature contractions that disappears on increasing the heart rate, returns as the heart rate drops; as does also the irregularity of partial heart block. In the case of heart block when the intermittency reappears in the pulse, auscultation of the apex also reveals complete silence during the pause. In the case of premature contractions, as the heart rate drops and the pauses occur in the pulse, there is nearly always the audible sound of the premature beat early in the diastolic period at the apex. The ectopic beat thus may or may not come through to the carotid or the radial.

The waxing and waning of *sinus arrhythmia,* revealed on careful examination, is exaggerated by forced respiratory movements and is thus easily identified whenever present. It is rarely found unless the heart rate is well below 100 per minute.

When the heart rate doubles itself or increases by a definite multiple following exercise, amyl nitrite, or nitroglycerin, the presence of *partial heart block* is to be seriously considered. A coupling of beats may mean a rare 3:2 heart block, but it usually means a bigeminy, *viz.,* every other beat is premature and is followed by a long, postextrasystolic pause. A tripling may likewise be a 4:3 block, a trigeminy, or a rare interpolated *premature contraction.*

A *slow, regular rhythm* at the rate of 40 per minute usually means *heart block* but may, in rare instances, be a *sinus bradycardia;* in this latter condition there is a definite or slight rise in rate, according to the amount of exercise or amyl nitrite given. The rate does not increase by a multiple nor does it approximately double, as in the case of partial block. A rate below 40 is practically always due to *complete heart block.*

This condition is further suggested when there is little or no increase in rate following the exercise or amyl nitrite tests. A *rapid, regular rhythm* at a rate of between 100 and 120 per minute is usually due *to sinus tachycardia*, especially if it is susceptible to vagus influence. When the rate is between 120 and 180 per minute, *auricular flutter* is to be considered and is more likely to be present when vagus pressure brings about slowing that can be maintained for a few beats only. A rate between 180 and 240 suggests *paroxysmal tachycardia*, especially when there is the characteristic sudden onset and offset of the tachycardia.

I. SINUS TACHYCARDIA

Synonym: Simple tachycardia.

Definition: Sinus tachycardia is a sustained increase in the heart rate beyond the normal limits for the individual.

The disturbance is the evidence of a transient or persistent decrease in the vagus tone or increase in accelerator activity, a change such that the rate of impulse formation in the sinoauricular node is increased, *usually without any other disturbance in the mechanism, in the origin* or the propagation of the impulse. As a rule, a persistent rate above 90. and certainly one above 100 beats per minute in an adult with an otherwise normal mechanism, should be considered sinus tachycardia. In children, especially infants, the normal rate is higher. The fact that at *birth and during early infancy the rate is 130 to 146*, at two years 120, at four years 110, at eight years 90 to 98, in the adolescent of 15 years between 80 and 90, and in the normal adult 72 to 78 per minute on the average, makes a sliding scale necessary. Age must be an important consideration in the establishment of a natural normal heart rate.

Temporary or Transient Sinus Tachycardia: This is the commonest change of cardiac mechanism, and it occurs often with the slightest provocation and persists from a few minutes to a few hours.

It appears in perfectly normal individuals as a result of exertion, excitement or drug action, or from unknown psychogenic causes. The normal response to exercise is an increase in the heart rate resulting from a decrease of vagus together with an increase of accelerator tone.

CASE I: *Rapid Heart Action from Fear; Psychogenic Tachycardia:* T. W., a little darky boy of six years, was brought into the orthopedic service for treatment of a lame leg. He had lived in the country all his

life and was literally scared to death when he was brought to the hospital There was no history of severe infections nor of significant disease processes except that he was born with a deformed foot It was noted that he had always been a very nervous child

The physical examination was entirely negative except for a club foot on the left and a rather rapid heart action The laboratory studies revealed no pathological changes in the urine stool or blood It was noted that his heart rate was normal during sleep

An electrocardiogram was taken and revealed no abnormality other than a high grade of sinoauricular tachycardia with a heart rate of 136 per minute He was so scared of the electrocardiographic procedure that it was impossible to get a tracing when his heart rate was low

The orthopedic treatment was carried out and he was discharged improved

In exercise these changes are a response to increased venous return and to changes in the blood possibly including slight relative oxygen want the accumulation of acid metabolites of muscular activity and augmented epinephrine output. The increased demand for oxygen in all tissues of the body including the heart itself must be supplied by an increase in circulation In the ordinary tolerance test of exercise the heart rate will rise from 20 to 30 beats as a result of mild exertion but there is always a fall to the normal level within two minutes

Diagnosis If there is any doubt as to the diagnosis electrocardiographic studies should be employed if available This method of precision will show a perfectly typical normal mechanism with sequential P waves and narrow Q R S T complexes with shorter diastolic or T P intervals consequent upon the increase in rate

Emotional psychic or psychogenic factors may increase the heart rate and maintain it at a high level for shorter or longer periods of time This is especially true in neurotic patients with either neurocirculatory asthenia or postinfectious vagus lability who may run a simple tachycardia for shorter or longer periods of time Even in these the pulse rate drops to normal especially during sleep Anxiety neuroses and neurasthenia show as part and parcel of their clinical manifestations a distinct imbalance in the sympathetic or involuntary vegetative nervous system

CASE II *Tachycardia of Neurovascular Asthenia* W S a negro aged 31 complained of palpation weakness shortness of breath giddiness and vertigo His symptoms had begun shortly after he had taken a job

as strikebreaker on the water front The scab work of a longshoreman was nerve wracking as well as strenuous He had previously been unemployed and had never done anything more than porter work. He had had an influenzal infection several weeks before he had undertaken the strenuous duties on the wharf.

The physical examination showed an anxious young man with rapid respiration The tachypnea definitely grew worse as his case was being considered He was slightly flushed and at times showed pallor He was of the asthenic type There were no major stigmata or hysteria Tumultous action of his heart at a rate of about 120 to 130 per minute was conspicuous The blood pressure was found to fluctuate considerably and be quite labile sometimes it was 150/90 but usually about 100/70 The heart was not definitely enlarged There were heard no significant murmurs nor abnormalities of the heart sounds The lungs showed no rales The liver was not tender No edema was present in the extremities.

The electrocardiograms recorded only a sinus tachycardia of 110 and no other deviations from normal

A consideration of all the facts lead to the conclusion that the patient was suffering from a sympathetic nervous imbalance the result of psychic and physical strain The diagnosis of neurocirculatory asthenia or the effort syndrome was made He was reassured put on graduated exercises and improved considerably He was advised to do lighter work under less severe and less strenuous circumstances

Drugs that usually affect the heart rate are amyl nitrite nitroglycerin atropine quinidine epinephrine ephedrine and nicotine Amyl nitrite effects a reduction in vagus tone as a secondary change due to the reduction of blood pressure Atropine paralyzes vagus endings peripherally as does quinidine to a less extent Epinephrine and ephedrine primarily *stimulate accelerators Nicotine in excessive doses will have a similar effect* while in smaller doses or in early *poisoning the opposite vagus tonic effect* is predominant The transitory or more persistently increased heart rate beginning insidiously and ending in the same fashion may be recurrent when there is a return of the exciting factors

Case III *Rapid Heart Action of Asthmatic Bronchitis and Adrenalin Administration* C H a white boy of ten years was seen in his home in an acute attack of respiratory distress During the previous week he had had an acute coryza with some fever and pain in the face soreness in the throat and hoarseness The process rapidly involved his paranasal sinuses During the night after the sinusitis appeared he suffered a tightness in the chest and shortness of breath He had been given an injection of adrenalin

which did not relieve him very much but made him nervous and caused his heart to palpitate. He had had previous attacks of the same trouble each winter, usually at Thanksgiving and at Christmas time. He had had no other infectious diseases

On physical examination he showed the evidences of a status asthmaticus and subacute nasopharyngitis and an asthmatic bronchitis. He began to expectorate blood tinged sputum in large amounts. The palpitation and tachycardia persisted.

An electrocardiogram was taken and showed, as the only abnormality, a sinus tachycardia. He was put under an oxygen helium tent and was given an ampule of 0.4 G of aminophyllin intravenously. After 12 hours the tightening in the chest began to let up and there was a rapid clearing out of purulent exudate. Within a week he was able to go back to school. The heart rate gradually dropped back to normal.

A prolongation of the period of rapid heart rate, that is a persistence of the sinus tachycardia, leads to the suspicion of a more serious disturbance, such as a postfebrile or infectious injury of the myocardium, especially when the heart rate remains over 100, with the patient under basal conditions Low grade chronic focal infections of the teeth, tonsils, accessory sinuses, lungs, the prostate, cervix or the gallbladder and more rarely in the heart itself, may produce no pain and very little rise in temperature, but may be the source of trouble.

Febrile reactions from acute infections, with a few rare exceptions, will produce a rise of from seven to nine beats for each degree of fever Tuberculosis is especially prone to produce a high rate except in rare instances, where it involves the basal meninges and secondarily stimulates the vagus. Typhoid fever is characteristically accompanied by a relatively slow heart rate. Chronic pelvic inflammatory diseases are often subfebrile, yet often present a tachycardia. Influenzal infection occasionally damages the heart to such an extent that the tachycardia persists and other evidences of myocardial damage appear sooner or later.

CASE IV. *Febrile Tachycardia of Lobar Pneumonia:* W. C. H., aged 26, was awakened during the night with a sharp pain in the region of the heart, a chill and high fever. Early during the previous day he had gotten wet but had continued to work. Late in the afternoon he began to feel unusually tired and at supper time he did not care to eat. His sleep was rather disturbed by restlessness and he awakened at about 2 A. M. with a chill, fever, and a pain in the left chest. The pain was worse on deep breathing His breath was short. He was somewhat nauseated and tried to vomit.

The physical examination showed an anxious definitely cyanosed young man There was marked respiratory distress an expiratory grunt and a rate of 40 per minute He had a fever of 101° and a pulse rate of 140 per minute The respirations were shallow The examination of the heart showed nothing but a rapid heart action The blood pressure was low, 110/80 There was increased vocal fremitus and dullness in the left base posteriorly A distant leathery pleural rub changed the bronchial breath sounds and sharp crepitant rales were heard over the left lower lung The signs of consolidation were unmistakably in the lower lobe of

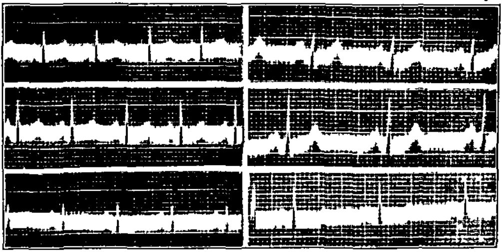


FIGURE 4 Febrile tachycardia of lobar pneumonia

the left lung The sputum was like prune juice and contained many pneumococci of Type I

The leucocyte count was 21 000 The patient was given antipneumococcus Type I serum A total of 150 000 units brought his temperature down to normal within 30 hours and his symptoms were greatly relieved

The electrocardiograms (Fig 4) showed sinus tachycardia with a return to the normal rate as soon as the fever disappeared

Among the metabolic disturbances obesity apparently tends to increase the heart rate while the outstanding condition of thyrotoxicosis or hyperthyroidism characteristically gives a considerable rise in heart rate that is roughly proportional to or is a rough index of the degree of increase in the metabolic rate

CASE V Toxic Tachycardia of Hyperthyroidism with Myocardial Damage A B a negress aged 25 was admitted complaining of nervousness throbbing of the heart prominence of the eyes and jaundice Her symptoms had begun rather suddenly during the previous year She

found herself quite nervous after the death of her father She was pregnant at the time and her nervousness increased throughout her pregnancy and was made distinctly worse by an almost exsanguinating hemorrhage and sepsis that she had at the time of her second parturition six weeks previously She had recovered from the infection very slowly and had never regained her normal strength or composure She complained of fatigue at the slightest exertion and suffered severely from palpitation The jaundice disappeared about two weeks before admission to the hospital It was only associated with mild gastrointestinal symptoms

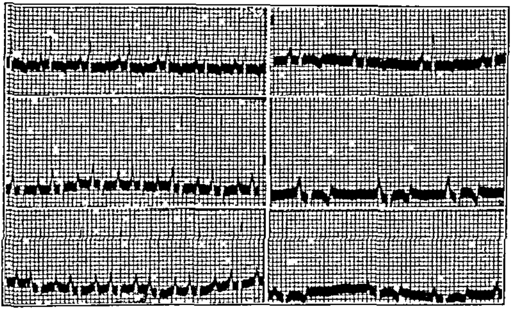


FIGURE 3 Toxic tachycardia of hyperthyroidism

The physical examination showed a very nervous jerking young negress with a very definite exophthalmos The jaundice had practically cleared up The skin was warm and moist The thyroid gland was diffusely symmetrically and bilaterally enlarged On palpation a slight thrill was felt and a slight purring was heard over the gland The retro manubrial dullness was slightly increased suggesting thymus enlargement The heart was at the upper limit of normal for size and was over active at the rate of 140 per minute The blood pressure was low 110/65 The lungs were negative and no rales were heard at the bases The liver was slightly engorged enlarged and tender there was a slight pitting edema of the extremities

The diagnoses of hyperthyroidism with slight myocardial changes and mild congestive failure were made

She was given three cat units of Thevetin which slowed the pulse rate from about 150 to 120 per minute She was then put on Lugols

I and K. I. solution, 5 mm., three times a day, and given absolute rest in bed. Under this regimen she quieted down and the heart rate dropped slowly and the metabolism dropped to about a plus 40 and the pulse rate to 100. She was submitted to surgical operation and after a subtotal thyroidectomy she improved remarkably. She was discharged apparently well with a heart rate of 90 and sinus arrhythmia.

Electrocardiograms shown in Figure 5 reveal a sinus tachycardia, a slight S-T sector and T wave changes, and later sinus arrhythmia with increased T wave negativity in all leads.

The disturbances in blood volume or shifts in blood mass, as in surgical hemorrhage and shock, or as a result of ether anesthesia, at first produce a distinct tachycardia.

The etiological factors concerned in sinus tachycardia are various, but no one pathological state is responsible. As a rule, the pathogenesis depends merely upon a functional imbalance between the effects of the vagus and the sympathetic or accelerator nerves. The symptoms of the condition are by no means characteristic and usually give rise to no complaint, although slight palpitation may have been noticed. Sinus tachycardia is to be differentiated from the other types of rapid heartbeat in which the point of origin and the character of the impulse formation, that is the mechanism of the beat, are abnormal. In the latter conditions the changes are primarily in the heart, while in sinus tachycardia the causes are usually extracardiac.

Clinical differentiation of the types of tachycardia is a simple matter in most instances because of the presence of definite or easily determined etiological factors in the history of the case. The insidious onset and the gradual offset are of similar type and character. Stimulation of the carotid sinus by pressure on the bifurcation against the transverse process of the cervical vertebrae usually results in a perceptible slowing, causing the rate to vary from minute to minute, especially during these maneuvers. Auricular flutter with 2:1 block gives a perfectly regular rapid heart action of 140 to 180 per minute. Under such conditions the more or less characteristic susceptibility of the A-V conduction path to a temporary increase in block produced by carotid sinus stimulation is usually sufficient for differentiation; the rate goes back to the previous rate even with continuance of the stimulus.

Paroxysmal tachycardias, especially those of auricular and nodal origin, present no etiological factors. The abrupt onset and the abrupt

offset characterize them In half the cases of paroxysmal *auricular tachycardia* carotid pressure has no effect whatsoever, no altering of the rate from minute to minute In the other half of the cases however carotid pressure or any other form of vagus stimulation will stop the paroxysms the high rate of 160 to 260 dropping to an absolutely normal rate of 70 to 90 beats per minute The patient during a paroxysm of auricular tachycardia is usually not very much distressed and certainly not to the extent expected at such a high heart rate

Nodal or *junctional tachycardias* are usually somewhat less influenced by carotid pressure than the susceptible auricular tachycardias and the auricular flutters but are usually more affected than the refractory half of auricular tachycardias

In *ventricular tachycardia* there is usually a slight irregularity of five to six beats noted in minute to minute counts The rate of the ventricular tachycardia varies more than the ordinary two beats per minute Usually there is also a history of some severe precipitating factor frequently vascular disease of the coronary system with or without cardiac infarction due to coronary thrombosis the latter often with a secondary pericardial friction rub and frequently also with pulmonary edema as accompanying frothy blood tinged sputum Further evidence of vascular damage is usually to be found *e g* a reverberating aortic second sound suggesting aortic and coronary sclerosis and a systolic murmur The ventricular pacemaker is usually below the level in the conduction system at which the cardiac nerves are effective and therefore there is no response to pressure on the carotid sinus exertion exercise change in position or amyl nitrite

Prognosis Sinus tachycardia especially the transient type is of no serious significance for it is a normal physiological response in otherwise normal individuals Persistent sinus tachycardia is usually a part of a definite clinical syndrome and its prognosis depends upon the prognosis of the underlying condition Under such circumstances it is entirely extracardial and therefore in itself simply suggests heart disease or the presence of myocardial damage It is therefore not a reliable sign of heart disease In the overly obese individual it may be taken as an indication for prophylactic weight reduction

Sinus tachycardia along with edema in the dependent parts dyspnea and orthopnea and some cardiac enlargement primarily dilatation is

of grave significance and indicates, along with the other signs, serious myocardial damage even in the absence of murmurs The presence of a sinus tachycardia, murmurs that signify chronic cardiac valvular disease, and the absence of the extracardiac disturbances that produce it, lead to the *suspicion of the all too frequent secondary infection of heart valves* which is usually due to anhemolytic streptococci (*viridans*) or an exacerbation of acute rheumatic endocarditis Persistence of the high rate under these conditions indicates continued activity of the process Post febrile sinus tachycardia as encountered in typhoid fever is usually due to a persistence of nerve imbalance Rarely does it suggest that the heart muscle has been damaged, and the length of time it persists is a rough indication of the amount of damage done In typhoid fever the myocardial damage consists of hyaline degeneration without exudation, so that it is practically always completely healed without any permanent defect or disturbance.

Treatment: In sinus tachycardia this is, of course, to be directed toward the cause When the latter is eliminated the disturbance usually subsides and no especial specific treatment of the tachycardia is necessary In tachycardias of *psychogenic origin* or of distinct, definite *imbalance in the vegetative nervous system,* the use of *vagus stimulating drugs such* as pilocarpine and acetyl choline have been advocated by the French In a case that presents reliable signs of cardiac damage, or even when these signs are not absolutely conclusive, there is good reason to suspect cardiac damage from previous infection or other causative agents It is safest to try rest in bed until a normal level is established, which should never take more than three or four weeks Sometimes we find the rate will not return to normal until we get the patient up *Then gradually* apply *passive motion* and a short regime of *exercises of gradually increasing grade* Then allow the patient to assume the upright position for short and longer periods Thus slowly there is a regaining of the normal nerve balance to the point where the heart will carry its load without *abnormal increase in rate*

II SINUS BRADYCARDIA

Synonym: Simple bradycardia

Definition: Sinus bradycardia means a decrease in the heart rate below the normal for the individual with respect especially to age It is

the evidence of a temporary, transient, persistent, or permanent increase in vagus tone, such that the rate of impulse formation in the sinoauricular node is decreased without any other disturbance in the mechanism of the origin or propagation of the excitatory impulse. As a rule, any heart rate below 70 beats per minute in a child or young adult with an otherwise normal mechanism may be said to present sinus bradycardia. The condition is considerably less frequent than its counterpart which has just been described, and may be either transient or persistent.

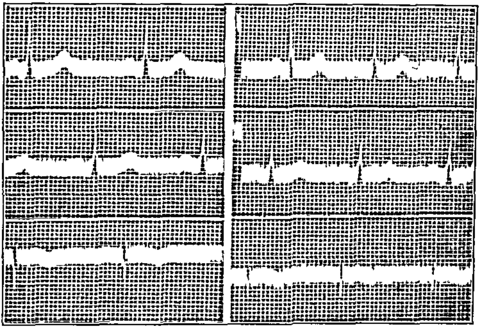


FIGURE 6. Sinus bradycardia of increased intracranial pressure.

Etiology: The etiological factors range from normal physical adaptation to serious central nervous system disturbances. Athletes in training are prone to have a slow heart rate. Among the general run of normal individuals it is not uncommon. The so-called vagotonic individuals will also present other evidences of increased vagus tone, especially with resulting mechanism disturbances in the gastrointestinal canal. Many normal individuals kept at basal conditions over extended periods of time will be found while at rest in bed to have a heart rate between 50 and 60 beats per minute. Starvation augments the slowing effect of rest on the heart rate. Reflex or direct vagus stimulation will cause a fall in the heart rate.

Increased intracranial pressure from a tumor or the accumulation of exudate in the basal meninges may produce persistent bradycardia

Jaundice of moderate grade appears to produce a characteristic sinus bradycardia The heart is slowed either through central nervous effects or more probably by direct toxic action on the sinoauricular node

CASE VI *Sinus Bradycardia of Increased Intracranial Pressure* A G aged 15 a young Cadian boy came into the hospital complaining of headache on the right side just above the right eye with increasing drowsiness and fever He dated his trouble from a cold in the head about four weeks previously Following the acute stages he had considerable discharge from his nose particularly from the right side and he began to have some headache The headache continued and grew worse as time went on and a slight fever apparently persisted and the pain developed and spread from the upper nasal side of the orbit to above the eye and into the frontal region of the head

Physical examination showed some swelling above the right eye and an exquisite tenderness in this area and up over the frontal region Examination of his nose revealed a purulent discharge coming from his right frontal sinus and evidences of a preceding coryza There was some slight discharge in the posterior pharynx and the tonsils were subacutely inflamed There were a few neck glands felt at the angles of the jaw and the posterior auricular and cervical glands were palpable on the right Roentgenograms showed suspicious clouding of the right frontal sinus

The heart was not definitely enlarged but was in a transverse position due to the high diaphragm The heart rate was very slow 60 per minute The blood pressure was moderately elevated 140/60 There were no murmurs or adventitious sounds heard over the heart the abdomen was greatly distended apparently the result of a paralytic ileus The extremities were negative The reflexes were normal and equal on both sides no pathological reflexes were detectable Examination of the ocular fundi showed questionable edema of the discs particularly on the right

The electrocardiograms (Fig 6) recorded a very definite sinus bradycardia of 60 along with left axis deviation probably largely positional Later on a low normal rate was recorded Exercise caused only a slight rise in the rate and atropine also had only a slight effect causing a rise to about 65 per minute

On the bases of the extreme bradycardia the ocular examination was repeated and the evidence of papilledema was noted With continuation of the bradycardia and choked discs there was evidence that there was probably some intracranial involvement

A diagnosis of penetrating abscess of the right frontal lobe was made and the patient was submitted to craniotomy The abscess was located

marsupialized and everted to drain. This patient's heart rate rose to a low normal of 70 during the operation and later to 75 per minute after recovery had taken place.

CASE VII. *Bradycardia of Catarrhal Jaundice:* R. G., Mexican, aged 13, came into the hospital because of the yellow discoloration of his eyes. His attention was called to a change in his sclerae by his friends. He had had no severe symptoms. There had been some malaise, feverishness and vague gastrointestinal uneasiness which had been present for several weeks. He remembered having had nausea, vomiting, and some

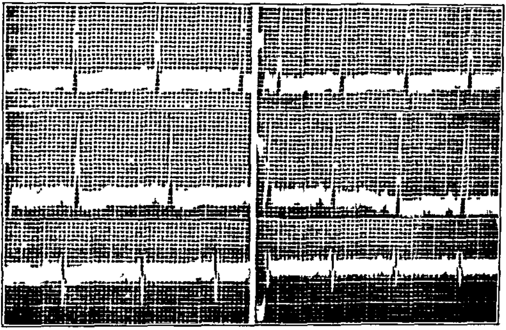


FIGURE 7 Sinus bradycardia of jaundice

dull pain in the upper abdomen, and constipation two weeks previous to admission. He took salts at this time and the local distress was somewhat relieved. The general feeling of indisposition persisted.

He gave no history of previous rheumatic fever or cardiac involvement. He did not know what his pulse had been before the jaundice. He had never had any palpitations, shortness of breath or edema. He had not had tonsillitis.

At the physical examination in the hospital his sclerae were found to be intensely jaundiced, and the mucous membranes of his mouth were icteric. His deeply pigmented skin made less conspicuous the jaundice of the body. He was slightly lethargic and a remittent fever persisted. His heart was well within the normal limits for size. No murmurs were heard but the rate was unusually slow, averaging between 70 and 80 per

minute. No change in the relative bradycardia could be produced by pressure on the carotid sinus, but exercise caused a definite rise in the rate. Atropine did not have a striking effect, as it usually does in bradycardia The blood pressure was low, 110/70 in both arms. His lungs were negative. The abdomen was distended and *an enlarged tender liver edge* was palpable.

The icterus index was 70, and the VandenBerg was positive direct Urobilin was present in the urine and in the stool A diagnosis of catarrhal jaundice was made.

The electrocardiograms (Fig 7) showed a perfectly normal cardiac mechanism and later on there was an actual tachycardia sinus bradycardia

The bradycardia in the presence of fever was attributed to the jaundice. In the hospital his jaundice began to clear following his duodenal lavage with magnesium sulfate. The gallbladder drainage procedure *brought forth slight evidence of duodenitis, but very little bile or detritus* from the biliary tract. After a few weeks his jaundice had cleared, his relative sinus bradycardia was displaced by an actual tachycardia with an increase in rate to about 80 per minute, and 105 later on, just before he was discharged from the hospital.

In convalescence from diphtheria, typhoid fever, and occasionally from influenza and other febrile conditions, patients often present a distinct decrease in the pulse rate. Sudden rise in blood pressure may cause a bradycardia by reflex vagus stimulation from the carotid sinus *This is especially marked as the outstanding part of the Branham syn*drome during the diagnostic closure test of arteriovenous aneurysm. *Women in parturition*, after prolonged labor, nervous and physical exhaustion, and fatigue, will have a slow pulse and heart rate. Anoxemia seems to predispose to sinus bradycardia.

Certain vagotonic drugs, especially acetyl choline and pilocarpine and occasionally physostigmine, may effect a slowing of the pulse, but morphine and digitalis rarely have this effect in the presence of a sinus mechanism. Atropine may be used to eliminate entirely whatever vagus effect may be present and thus identify the slowing in normal individuals.

Fainting attacks in individuals with slow pulses are usually vagal in origin. In unusually susceptible vagotonics, syncopal attacks may be precipitated by slight emotional disturbances. Some individuals are so susceptible that slight stroking of the neck by the barber in massage *after* shaving, or the drawing together of the coat collar by the fond wife as *she bids her husband farewell, may precipitate the syncopal attack*

Case VIII *Sinus Bradycardia and Attacks of Fainting Due to Sino auricular Standstill as a Result of a Hyperirritable Carotid Sinus Reflex* W M aged 25 an athletic young man complained of falling out attacks which occurred every time he got into a certain barber's chair He was greatly disturbed and began to believe that the barber had some supernatural influence over him was hypnotizing him and was perhaps bent on some mischief He tried other barbers in the same shop but had no similar experiences When put to close questioning he stated that the barber worked just about like any other barber but that his barber had perhaps a bit more power in his fingers particularly when it came to

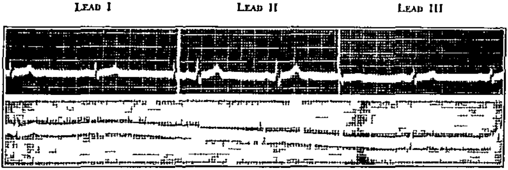


Figure 8 Sinus bradycardia with carotid sinus episodes Pressure in location of carotid sinus reflex

stroking the sides of the neck after shaving He was unusually vigorous in his massage on the skin and in rubbing in the shaving lotion

The young man had no other symptoms whatsoever There was nothing in the least suggestive of heart disease He had noted that he had a slow pulse His past history was absolutely negative for any etiological factor He had done a good deal of track work during his college days

The physical examination showed a stalwart young man who was a bit anxious about himself He was of the hypersthenic type The musculature was rather heavy and prominent *No other abnormalities were* made out in the careful study of the neck The chest was broad The heart was in the transverse position well within the midclavicular line The retromanubrial dullness was normal There were no murmurs or adventitious sounds The heart rate was 18 per minute The blood pressure was 118/71 The electrocardiograms (Fig 8) confirmed the diagnosis of sinus bradycardia

With the patient in a reclining position pressure was applied over the bifurcation of the carotid artery on the right midway between the inner end of the clavicle and the angle of the jaw There was inaugurated in the side of the neck in the hypersensitive carotid sinus vagotonic reflex

He could of course give no adequate explanation for his action nor could he see any reason for his peculiar sensation. He had of course fainted easily in life before on the slightest provocation but he had forgotten about *it until he was questioned. He had never had diphtheria* nor rheumatic fever nor any other serious infectious disease that might have involved the conduction pathways of the heart. He had no other symptoms of any sort.

The physical examination showed a well built middle aged man slightly over anxious. Nothing abnormal could be found in his neck. His chest was likewise perfectly normal. His heart was transversely placed and about in normal position. There was no evidence of enlargement, no murmurs or adventitious sounds were heard. The blood pressure was normal. The peripheral vessels were soft and pliable. The electrocardiogram showed no abnormality whatsoever.

It was concluded that the carotid sinus stimulation should be invoked. This was done and the sinoauricular standstill was demonstrated. The attack could be reproduced at will; the electrocardiograms (Fig. 9) present the evidence of the excessive vagotonia and simultaneous electrocardiographic tracings were made. The conclusion was that the patient had an unusually irritable carotid sinus and when pressure was brought to bear upon it by the final rites of departure, it precipitated the period of asystole and the accompanying cerebral anemia. The patient's young wife faith*fully refrained from compressing his carotid sinuses and administered* regular doses of atropine 1/100 grain t. i. d. She thus succeeded in preventing the disturbing reaction and they lived happily ever after.

Slowing of the heart rate may result from circulatory changes in the region of the node, a not uncommon event in patients with arteriosclerotic heart disease usually after the blood pressure has fallen. Apparently the pulse is not slow when hypertension is persistent, as it is in the transient type.

CASE X. *Carotid Sinus Episodes. Giddiness, Vertigo, Faintness and Falling-out Attacks as a Result of Reflex Inhibition of the Heart.* F. W. B., a petty gangster of Treasure Island, aged 66, became alarmed at recurrent attacks of dizziness and fainting. He had followed somewhat in the footsteps of Jean LaFitte and actually had a rendezvous down the island near the pirate's old live oak grove on Galveston Bay. The F. B. I. or the G-men had apparently given him the "jitters." He had had a great increase in the number of attacks, not only of giddiness but also of unconsciousness, and had fallen out quite often. He first noticed these attacks of vertigo and syncope on backing his car out of the garage unusually rapidly. Symptoms of giddiness also recurred when he suddenly *turned*

his head to the side, which he apparently had been doing repeatedly perhaps as a defense reaction

Upon hearing this story dramatically told and surveying him critically and noting his make up it seemed very probable that he was having carotid sinus episodes He was a member of the old order and still wore the high, stiff collars that bound his neck closely and exerted considerable pressure upon the region of the carotid sinuses As a result of this binding when he turned his head to the right it impinged the hyperirritable

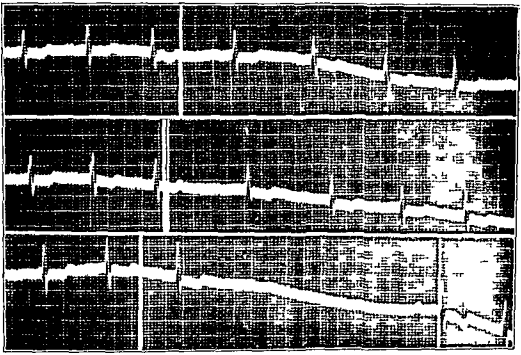


Figure 10. Sections from Lead II with carotid pressure applied

The pulse waves were definitely anacrotic The blood pressure was elevated to 160/100 This patient apparently had calcareous disease of the aorta aortic stenosis probably coronary artery disease and some decrease in the circulation of the heart

The symptoms such as he had recently shown are commonly associated with an exaggerated carotid sinus reflex as pointed out by Marvin The administration of Novatropine 1/16 to 1/10 grain t i d controlled his severe attacks and gave him renewed confidence in himself There were some auriculoventricular conduction disturbances developing later in this patient and the possibility of Adams Stokes disease had to be considered However he gradually developed myocardial insufficiency incapacitating him completely and finally bearing him to his reward

The electrocardiograms (Fig 10) showed the evidences of sinus bradycardia and auricular standstill following mechanical stimulation of the carotid sinus Later auriculoventricular conduction disturbances were recorded All of the disorders were removed by the use of the atropine group of drugs

The etiological factors or causes and the pathology may be quite varied since there are no specific local lesions so far as is known The condition is usually asymptomatic but in the aged and especially in the presence of cerebral arteriosclerosis and a low blood pressure giddiness vertigo and in the more severe cases syncope may result as complicating symptoms

Diagnosis *Slow heart action may be produced by conditions other than functional or reflex sympathetic nervous influences* Organic lesion bradycardias are of much more serious moment than sinus bradycardia There may be partial or complete auriculoventricular heart block with slow idioventricular rhythm in the latter that must be differentiated Characteristically in sinus bradycardia the effects of the vagus and accelerator nerves are still present and may be tested with the usual response *i e* a gradual increasing rate after exertion or atropinization In partial heart block the response usually results in an increased rate *as a direct multiple of the previous rate i e* a doubling if 2 1 block was present and an increase by a quarter in a 4 3 block In complete block there is usually little if any response to exertion except perhaps in cases of rheumatic pancarditis The rate in partial block is usually slightly higher than that found when a complete block is present When there is absolute dissociation the idioventricular rate of 30 or below is usually present except when this dissociation has been induced by digitalis

intoxication, under which circumstances the rate may be as high as 60 with a regular independent idioventricular rhythm.

In the partial heart block, at the time of the pause in the rhythm at the wrist, there is usually complete silence at the apex. It is essential to check this up carefully, for frequently every alternate beat is an early *premature contraction, with insufficient pressure to open the aortic cusp,* while every other or normal beat is conducted and effective, producing a slow, regular rhythm. This type of premature contraction, like other types, usually disappears on exertion and the pulse rate will be more than doubled. It is, therefore, essential to auscultate the apex carefully in determining whether or not the slow pulse is due to a sinus bradycardia, a heart block, or a bigeminy with very early and weak ectopics Electrocardiograms must again be the final court of appeal Sinus bradycardia is the slowed normal mechanism in which the P R interval may be at the maximum normal and the T-P interval greatly increased

Prognosis: This depends upon the precipitating factor Usually sinus bradycardia is totally innocuous It may, however, occasionally be present in heart disease and even along with congestive failure.

Treatment: This likewise must be guided according to the etiological factor that is present. Where a definite etiology is demonstrable, steps should be taken to remove the disturbance Usually the slow heart in itself causes no symptoms and no interference is called for When the vagus irritability is so great as to cause syncopal attacks, even after the removal of exciting factors such as nicotine or pressure, tincture of belladonna in 1 cc. (16 minim) doses, atropine sulfate up to 1 mg ($^1/_{65}$ grain) or homatropine bromethylate up to 6 5 mg ($^1/_{10}$ grain) or paredrine hydrobromide 30 to 60 mg ($^1/_2$ to 1 grain) are indicated in daily rationed doses.

III. SINUS ARRHYTHMIA

Synonym: Respiratory, vagus, or phasic arrhythmia.

Definition: This most benign irregularity is due to rhythmically, regularly recurring and alternating periods of gradual slowing down and speeding up of the impulse formation within the sinoauricular node. The vagus nerve governs the rate of impulse *formation.* The vagus tone may fluctuate with the events of the respiratory cycle just as do the rhythmical variations in blood pressure, the waves incident to the rise *and fall of the irritability of the respiratory center* In the youthful heart,

especially with deep inspiration the vagus tone decreases and the heart rate quickens while during expiration the reverse takes place and the heart rate slows There is thus produced a regular irregularity a waxing and waning of the rate of the heart In some instances the respiratory effects may be just exactly the opposite in which case this disturbance is called paradoxical Occasionally there is no relation to respiration whatsoever and at times a single long diastolic pause may be recorded without

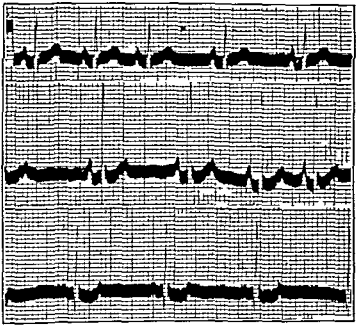


FIGURE 11

any previous or subsequent quickening This is the type that may occasionally be associated with sinoauricular standstill

CASE XI *Sinus Arrhythmia That Was a Source of Worry* B J aged ten was brought to me by his mother because of an irregular heart action a general irritability and inability to gain weight The irregular heart action was a matter of much concern For several years the boy had frequent attacks of tonsillitis and bouts of fever that lasted from four to five weeks He had been in a general rundown condition and apparently had been getting worse and a question as to whether or not a tonsillectomy should be done was raised There was some hesitation because the patient s older sister had died during a similar operation under general anesthesia at the age of five The patient had apparently been sickly all of his life

The father had contracted syphilis during the war but had been vigorously treated and was serologically negative in 1925, three years before the patient's birth In 1934, however, he had had a nervous breakdown of general paresis which responded promptly to fever therapy During the first year of his life the patient had a great deal of gastro intestinal difficulty and responded to no formula until he was put on Swiss goat's milk and was moved from Georgia to Hawaii At the age of four he was brought back to Arkansas where the cold damp winters brought on much trouble His last four years had been spent in Louisiana He had had repeated colds from the age of six to ten

The physical examination showed an under developed somewhat pale boy with no definite stigmata of congenital syphilis There was nevertheless a suggestion of poor protoplasmic stamina The teeth were quite irregular and the tonsils were hypertrophic with some scar tissue about them and the glands at the angles of the jaw were enlarged The other regional lymph glands showed some hypertrophy and those in the epitrochlear region were definitely shotty

The chest was small and thin and showed a definite rosary and groove as evidence of old rickets The retromanubrial dullness was somewhat increased to 5 cm and the cardiac dullness extended 3 cm to the right and 8 5 to the left The heart was thus at the upper limits of normal for size A very definite sinus arrhythmia was noted and on careful auscultation there was accentuation of the basal sounds and a faint and distant high pitched diastolic murmur A slight systolic murmur was heard over the tricuspid area

The abdomen was negative The spleen could not be felt and the liver came to the costal margin

The electrocardiograms (Fig 11) showed a very definite sinus arrythmia and aside from a partial inversion of the T wave in Lead III there were no other abnormalities The Lead III changes with the physical findings of a rheumatic aortic regurgitation suggested myocardial damage Sinus arrhythmia is in itself innocuous it is usually present in normal youths Mackenzie has maintained that it is evidence of an absolutely uninjured heart It is an unusual finding in a patient with rheumatic heart disease but it does occur and cannot therefore be accepted as evidence against involvement of the heart Sinus arrhythmia is frequently mistaken as in this case for a serious mechanism disorder The irregularity cleared up with exercise and a slight rise in the heart rate was induced

All of the types depend upon rhythmical changes in the vagus tone The condition therefore, usually is of physiological significance in youth and in the aged It occurs less commonly after adolescence or in adult

life, until the increased vagus tone of advancing age or early senility comes into play. Nervous or general irritability greatly exaggerates the disturbance. Increasing the heart rate by slight exercise or the administration of amyl nitrite or atropine abolishes it and it practically never persists when the heart rate is above 100. Digitalis intoxication may be the causative factor in otherwise normally nonvagotonic individuals.

In the rarer cases of slow arrhythmia which do not become regular with the rate rise after the injection of atropine, thoughts must be directed to the possibility of heart block, vagus neuritis tumor, meningitis, or increased intracranial pressure from some grave intracranial disease. It may occasionally be present in an adult who presents other signs of cardiac failure. Sinus arrhythmia, therefore, cannot be taken as an absolute sign of a normal heart in spite of Mackenzie's dictum. Sinus arrhythmia rarely produces any symptoms except in the overly nervous and sensitive individual who is disturbed and worried by the irregular palpitation.

Diagnosis: The disturbance is one of infancy, childhood, adolescence, and senility. The frequency with which the condition is mistaken for some serious arrhythmia, such as auricular fibrillation, makes its recognition of considerable significance. Chief among the diagnostic signs is the fact that the irregularity disappears when the heart rate rises to 100 or above in response to exercise, amyl nitrite, or atropine. Slow deep inspirations and expirations, especially when forced, increase the respiratory arrhythmia. This reaction is quite characteristic, since none of the other irregularities are so characteristically affected; although premature contractions are often precipitated by such maneuvers, they appear quite irregularly and show no cyclic tendency. Since auricular fibrillation rarely presents this characteristic phasic waxing and waning, and the irregularity is exaggerated by increasing the heart rate, the differentiation should not be difficult at all.

In the most exaggerated form of sinus irregularity there is occasionally complete sinoauricular standstill or sinoauricular block, and A-V heart block may be suspected This is ruled out with difficulty, since the dropping out of the complete A-V cycle and the failure of a ventricular response alone have the same peripheral effects. When, however, the long interval comes at the end of expiration, and there is a gradual slowing up to the point of the dropped beat, followed by a gradual speeding

up after the dropped beat it is quite probable that a vagus effect is to be considered, especially if the irregularity is abolished by mild exercise Here again the *electrocardiographic method alone will absolutely deter mine the state of affairs* as it is the only means by which a diagnosis of sinoauricular standstill can be made The electrocardiograms are gen erally *characterized* by a *gradual lengthening of the diastolic period* *i e* of the T P interval up to the longest one and a gradual decrease to the shortest one The P Q R S T waves are always in normal array

Prognosis This is usually excellent but depends of course upon the age of the individual and the other accompanying cardiac findings In the infant child or adolescent sinus arrhythmia is a normal physiological phenomenon but in an adult especially after middle age it may be of *some pathological significance*

Treatment This is rarely required for the condition itself Reassur ance suffices to allay undue anxiety In the nervous patient bromides may be of some value in suppressing any imaginary distress of this slight disturbance

IV ECTOPIC REGULAR RHYTHMS

Abnormally increasing vagus tone may cause ectopic regular rhythms *with slight if any, changes in rate by a shifting of the pacemaker* appar ently from the head to the tail of the sinoauricular node or to lower levels in the specialized tissue If the increase in tone is sudden and temporary *sinoauricular standstill is the result If however the increase* is persistent a lower center must take up the function of the pacemaker This disturbance is then simple and its presence is usually of nervous or functional origin

The ectopic rhythm may be nodal or junctional *i e* with the pace maker in the A V node or in the junctional tissues both of which are supraventricular foci In rare instances the inhibition of impulse forma tion may also include the A V node and bundle so that an idioventricular rhythm may actually arise Usually this occurs however only in the presence of distinct pathology in the conduction tissues *When the pace* maker is displaced to the lower centers the cardiac rate is usually defi nitely decreased and the lower the level of the new pacemaker in the junctional tissues the slower the rate will be The *rhythms of low* junctional, and especially of ventricular origin are regular and are quite uninfluenced by the vagus nerve effects

V. AURICULOVENTRICULAR RHYTHM

Synonyms: Nodal, junctional, auriculoventricular or A-V rhythm.

Definition: An A-V rhythm, with generally a moderately slow rate, is one in which a focus in any part of the A-V node or the A-V bundle (His-Tawara) acts as pacemaker of the heart. This occurs usually because of depression, of functional, nervous or pathological organic origin, of the higher, normally more rhythmical, sinoauricular node or pacemaker. The condition is recognized usually and differentiated absolutely only in the electrocardiogram.

The impulse discharged from the ectopic pacemaker in A-V rhythm necessarily takes an abnormal or retrograde course to and through the auricle and at the same time speeds on to the ventricle. Thus the auricle may just precede the ventricle or both chambers may contract nearly simultaneously, or the ventricle may actually contract ahead of the auricle.

The type of A-V or nodal rhythm depends chiefly upon the location of the pacemaker. The varieties electrocardiographically recorded are: Type I, where the P-R interval is greatly shortened; Type II, where there is no P-R interval and Type III, where there is actually an R-P interval; Type IV, where there is a gradual shifting from Type I to Type III. In the first type, the pacemaker is presumably located in the extreme upper part of the A-V node. Thus, the auricles are retrogradely activated ahead of the ventricles, but, since the impulse starts from a point between the sinoauricular node and the ventricle, it arrives at the latter after a shorter than normal P-R interval. In the third type, the pacemaker is nearer the ventricle, which is consequently first to be excited, while in the second type the locus is intermediate. The explanation of Type IV cannot be given in a few words, but is probably rarely due to actual migration of the pacemaker from a higher to a lower position, as was once believed. The types of nodal or A-V rhythm are of no special clinical significance, inasmuch as they cannot be recognized excepting by electrocardiographic means.

The condition is relatively uncommon. It was frequently reproduced in perfectly normal young individuals by F. N. Wilson through a combination of atropinization and carotid sinus pressure. It appears after acute fevers and frequently in digitalization, sometimes in the presence of localized circulatory changes or myocardial disease, especially in the auricle in and about the sinoauricular node. The rhythmicity of the

new lower center is less than that of the sinoauricular node The conditions previously mentioned as factors in the production of increased vagus tone may precipitate nodal rhythm by depressing the normal pacemaker. Adrenalin, aconitine, or pilocarpine are drugs that occasionally cause it. Excessive doses of nicotine and ether, especially with an anesthetic anoxemia, *predispose to it. Nodal rhythm of Type IV has been* recorded following cardiac infarction Besides simple depression of the sinoauricular node, AV rhythm may sometimes result from an abnormal

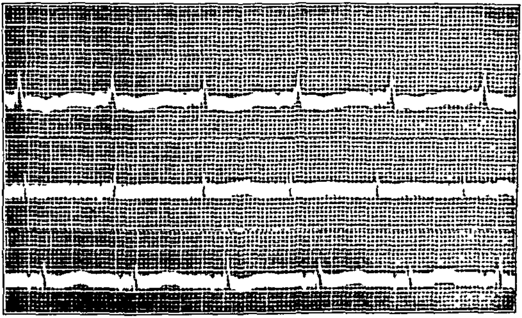


FIGURE 12 Auriculoventricular rhythm following C I and M I (Double standardization)

increase in rhythmicity of the auriculoventricular node, which then usurps the pacemaking function *The rate will then be high*

CASE XII *Auriculoventricular Rhythm Following Painless Coronary Thrombosis and Myocardial Infarction:* T. R., aged 67, a white laborer, had an acute onset of severe shortness of breath and palpitation accompanied by wheezing, an expiratory stridor, considerable cough, expectoration of blood tinged frothy sputum, nausea and vomiting, fever, extreme weakness, and dizziness. Breathing was extremely difficult at times

The physical examination showed a plethoric obese old man who was pale and gray and somewhat emphysematous. His vital capacity was reduced to about 50 per cent of normal, some dullness was present at the lung bases and some fine subcrepitant râles were heard throughout both lungs. The breathing was of a distinctly asthmatic type and there

possible explanation of these disturbances can easily be visualized as a circus mechanism such as has been accepted as the initiating and maintaining mechanism in auricular flutter and fibrillation.

In general in only half the cases is the abnormal focus in the auricle susceptible to the influences of the vagus nerves, and either a complete effect may be elicited or none whatever from stimulation of these cardiac

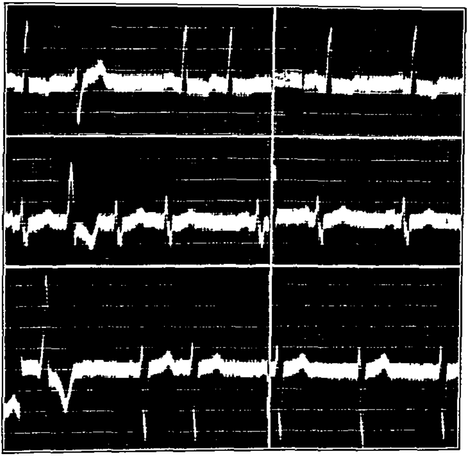


FIGURE 13

nerves. When effective, as it is in half of the cases, carotid sinus stimulation completely suppresses the abnormal mechanism within one cardiac cycle. According to recent work, there is apparently a definite relationship between disturbances of the calcium-potassium ratio in the heart muscle, which is reflected to some extent in the blood serum, in patients with serious heterogenetic rhythm disturbances. Magnesium, calcium and potassium ions are apparently in a balanced solution in the heart

muscle cells These considerations are of some practical significance in that the disturbances may be promptly and spectacularly affected in varying the concentrations of these ions by the therapeutic administration of relatively massive amounts of them intravenously or by mouth

CASE XIII *Extrasystole Causing Irregular Heart Action, Relieved by Thyroid Extract and K I* A W H, a housewife of 38 was considerably disturbed by irregular heart action, a fluttering sensation in the chest general weakness and a slight breathlessness She dated her trouble from the time she came to the Far South from the North where she had always felt well However, she had had an attack of diphtheria in childhood and frequent tonsillitis up into adolescence at which time she also had some arthritis and her tonsils were removed She had influenza in a mild form in 1919, with some pleurisy as a complication of the infection She had had two children without any difficulty in the North followed by one questionable miscarriage, and a final pregnancy in 1928 when she was delivered by a Caesarian section

She had noticed some slowing up of her mental processes and an increase in susceptibility to cold, along with distention and recurrent arthritis of the spine and the small joints of the hand

The physical examination showed a moderately obese woman with a very slight thinning of her eyebrows and some puffiness of her face Her heart was not increased in size There was a systolic murmur heard at the apex and at the base Premature contractions were frequent and occasionally noticed as coming in short runs Electrocardiograms (Fig 13) showed them to be of auricular and ventricular origin The abdomen was somewhat distended and the gastric tympany extended up into the precordial area The blood pressure was normal 120/75 There was a slight tenderness in the gallbladder region No other abnormality was noted

Evidences of gallstones were found on x ray study and a cholecystectomy was done The sharp pains in the abdomen no longer recurred but the distention was not very much relieved and the irregular heart action persisted There were some slight menstrual disturbances, and theelin was given This improved the menses to some extent and the distention somewhat, but had no effect upon the disordered heart action Phenobarbital gave some relief, however, but she was sensitive to barbiturates and quinidine sulfate These drugs could, therefore not be given over any length of time Potassium iodide likewise caused salivation

Her B M R was definitely reduced puffiness was noted to have appeared about her face She was put on potassium iodide in 15 grain doses t i d and thyroid extract and rapidly, the dosage increased to three

grains a day She was completely relieved of all her symptoms there was no increase in the heart rate, in fact a definitely slower regular pulse followed the thyroid medication

VII EXTRASYSTOLIC ARRHYTHMIA, EXTRASYSTOLES ECTOPICS, PREMATURE CONTRACTIONS OR SYSTOLES INTERMITTENCY OF THE PULSE

Definition *Extrasystolic or ectopic arrhythmia is the commonest* irregularity of the heartbeat It results from the occurrence of premature contractions that arise or are initiated precipitately from foci in the heart muscle outside the sinoauricular node

This the commonest disorder of the heart action is usually an irregular interruption of the normal regular rhythm It may be the result of nervous, mechanical or chemical stimuli worry or atmospheric conditions *especially increased temperature and humidity digestive disturb*ances with distention and intoxications, or toxemias of infections Drugs as digitalis caffeine nicotine, barium chloride calcium aconitine, chloroform ouabain arsphenamine ephedrine, and epinephrine may be initiating factors in susceptible individuals

The local defects resulting from nervous circulatory, or mechanical changes or influences usually produce no pathognomonic, anatomical *changes that are demonstrable in even the most careful microscopic exam*ination There must be of course physical and chemical changes in the affected heart muscle cells Consequently, physicochemical rearrangements in localized groups of heart muscle cells seem to be the best etiological, anatomical and physiological explanation of the phenomena These may definitely be related to the potassium-calcium magnesium content of the heart muscle cells

The type of extrasystole depends upon the point of origin The disturbances may originate either within or outside of the specialized tissue *i e*, in auricular junctional or ventricular tissues or heart muscle cells These supersede the normal impulses and are generally followed by post extrasystolic pauses The pauses are usually compensatory Occasionally when the premature contraction occurs in early diastole interpolation results *i e*, a premature ventricular beat is seen between two normal *sequential responses to sinoauricular impulses.* In this latter disturbance both the interpolated beat and the normal systole which closely follows

it are weak The condition is not distinguishable from paired premature beats, except in the electrocardiographic tracing

Premature contractions that disturb the basic regular rhythm may originate in a single focus or in multiple foci may occur at quite irregular or regular intervals, as every other beat producing bigeminy, every third beat, trigeminy, every fourth beat quadrigeminy, etc In auricular flutter and fibrillation, according to the traditional view all the impulses are of auricular ectopic origin These disturbances may however, also be further complicated by accompanying ventricular premature contractions

In auricular ectopics only the auricular muscle is invaded by the impulse in abnormal sequence transmission through A V node to the ventricles is along the normal pathway Such ectopics are not followed by pauses sufficient to make the sum of the durations of the pre and postextrasystolic cycles equal to the length of two normal cycles as is the case in ventricular ectopics The auricular ectopic impulse touches off the sinoauricular node early, and the recovery of the latter immediately begins is completed in the normal time, and the postectopic pause *is accordingly short*

In case of most junctional and practically all ventricular premature contractions, the impulse, traveling slowly backward does not reach the auricle *or sinoauriclar node because it meets the oncoming sinoauricular* impulse Thus both the latter impulse and the retrograde ectopic impulse are mutually extinguished The compensatory pause of the *ventricle is simply the time it must wait until arrival of the next sino* auricular impulse

The mechanical efficiency of the premature contraction is in inverse proportion to its prematurity The most premature beats of course, come at a time when the ventricles are incompletely filled the resulting *contraction is feeble and the pressure generated may be insufficient to* open the aortic cusp and consequently, the pulse wave is not propagated in the systemic or the peripheral circulation Thus the cardiac energy is dissipated or wasted as no onward movement of the blood is effected The peripheral blood pressure of the premature contraction is usually low, but that *of the impulse following the pause is distinctly increased* When occurring late in diastole the concomitant blood pressure rise is usually sufficient to open the aortic valve and allow the wave to spread into the periphery But at best, premature contractions are weaker and

less efficient than normal beats and the more premature, the less efficient they are.

Symptoms: Many normal individuals are not conscious of the presence of an *extrasystolic arrhythmia unless they palpate their own pulses.* The physician must discourage such practice and be careful not to call a patient's attention to the presence of the irregularity if he is unaware of it, lest he become sensitive to the disorder. If he is cognizant of the disturbance the physician must minimize its significance and reassure the patient. Nervous, high-strung, hypersensitive individuals, however, have many subjective symptoms and they are conscious of every disturbance, the pause and the powerful beat following the premature contraction. *They may experience transient giddiness, vertigo, weakness* and momentary distress, with a disagreeable ill defined precordial or substernal sensation. The hypochondriac may have the symptoms in a much exaggerated form. To him it appears that the heart turns over, jerks, and twists, and often seemingly sends the wave through forcibly to the top of the head. The irregular palpitation is most noticeable when the patient lies down to rest at night. Posture plays some part in this and it is especially a factor if the patient is lying on his left side or has his ear on a *pillow. However, the slowing of the heart incident to rest seems to be* the most important initiating factor. Long, deep, sighing respirations with holding of the breath often increase the irregularity. When a bigeminy is present, a distinct coupling may be felt.

A nervous patient with ectopics, unless most carefully and properly managed, is likely to become a confirmed cardiac neurosis case with dyspnea and anginoid pains. The disturbance may be persistent but transient or recurrent, isolated, multiple, rare or frequent, irregular or regular, *in its rhythm.* There are rarely any complications except, occasionally, when the disturbance is superimposed upon an already badly damaged heart, the insufficiency of which may distinctly increase as the result of the disturbed blood volume flow.

Diagnosis: The diagnosis of extrasystoles is rarely difficult. The bedside test, namely, that of disappearance with the increased heart rate resulting from exercise or the inhalation of amyl nitrite, will make the diagnosis of the extrasystolic irregularity quite certain. It disappears as *the rate rises to the neighborhood of* 120 and over, and certainly after it reaches 140 The rule that may be relied upon is that any irregularity

that persists at the rate of 140 or over is auricular fibrillation and of those disturbances that disappear when the rate reaches 100 to 120, the major ity are extrasystolic arrhythmias

Ectopics which are exceedingly premature do not open the aortic cusps consequently are not felt at the wrist and thus simulate the inter mittency of heart block and the pulsus deficit of auricular fibrillation Under these circumstances the second heart sound may be absent but auscultation over the heart will usually reveal the inefficient premature ventricular muscular element *i e*, the first sound of the extrasystole which is always produced even though at times it is faint The regular periodicity of respiratory sinus arrhythmia is never present The absolute regularity in the spacing of the first sounds in alternation serves to dis tinguish it from the coupling of ordinary ectopic bigeminy

The clinical differentiation or the point of origin of the premature *contractions is of academic rather than clinical interest and is at times* indeed a bit difficult

As was stated above an auricular premature contraction is usually *followed by an abbreviated postectopic pause* such that the two periods or cycles including the premature contraction do not equal two normal periods of regular rhythm Ventricular premature contractions are usu *ally followed by longer truly compensatory pauses The presence of an* interpolated ectopic is suggested by the occurrence of three beats in rapid succession within the space of little more than two normal ones with *heart sounds midway between apparently normally spaced beats*

Groups of three beats may be produced by the prompt occurrence of a second premature contraction after the first *i e* a doubling both beats coming either from the same focus or one from *one side the other* from the opposite side of the heart These simulate interpolation but they are often followed by a long postectopic pause Electrocardiograms recording *the disturbance in each of the standard leads afford the only* evidence as to the site of origin of the premature contractions

Prognosis As a rule the prognosis is good Premature contractions are compatible with otherwise normal heart function They are fre quently present in patients who show no reliable signs of heart disease Some patients are known to have had premature contractions for as long as 50 years and have lived the full span of life with apparently little inconvenience Persistence of the disturbance in an exaggerated form

occurs usually only in patients with other evidences of heart disease and the prognosis then depends upon the heart disease itself. The prognosis does not seem to differ, whether the ectopic beats be of auricular, junctional or ventricular origin, although the latter seems to disturb the mechanism the most. A multiplicity of the points of origin may well be of more serious moment in suggesting a more widespread circulatory disturbance The rate at which the extrasystoles originate seems to be of little significance, nor does the frequency of appearance of the disturbance seem to have any particularly definite bearing on the ultimate prognosis. Auricular extrasystoles, however, seem at times to be forerunners of fibrillation and paroxysmal tachycardia.

Treatment: Removal of any possible causative factors should be the first consideration. Habitual excessive nicotine and caffeine intake should first be curtailed. If drugs are used, as digitalis, aconitine, barium chloride, adrenaline or ephedrine, they should be temporarily suspended at the appearance of an extrasystolic arrhythmia. Gastric distention causing mechanical embarrassment should be corrected. A sojourn in the mountains is desirable for those that are further embarrassed and oppressed by the hot, humid season in low altitudes. The temperature and humidity may be reduced by modern air conditioning apparatus and living in the tropics made possible for most patients

Nervous individuals must be constantly reassured and instructed to avoid excitement and to take sedatives such as bromides or barbitals. An excessively acid urine calls for changing the reaction by the use of alkalis and this is sometimes followed by gratifying relief of the irregular palpitation.

It is hoped that application of the classical studies of the older physiologists on the effects of ions of potassium and calcium, along with those of sodium, upon the mammalian as well as the frog heart, will yield promising results. Beginning with the work of Ringer, it was shown that, independent of osmotic pressure, a balanced solution of potassium, calcium and sodium ions was necessary to maintain normal heart action As early as 1911, *Rothberger and Winterberg were able to* stop extrasystolic arrhythmias with potassium salts. Potassium deficiency is possibly a causative agent in extrasystolic arrhythmia of nervous, mechanical, or circulatory origin, but probably not when the irregularity is of toxic origin. In the latter, calcium salts are more effective, as they

are also in paroxysms of persistent ectopic impulse formation Recently these facts have been applied clinically by Sampson and Anderson who found that potassium acetate administered by mouth in from 1 to 5 Gm (15 to 75 grain) doses stopped the extrasystolic arrhythmia in half of their cases while Wolfe and Bellett have stopped paroxysmal tachycardia by intravenous calcium administration

In some patients the use of thyroid extract or atropine accomplishes the end in others quinidine is sedative while in some the use of digitalis is efficacious

VIII PAROXYSMAL TACHYCARDIA

Definition Paroxysmal tachycardia consists of rapid regular rhythm of precipitate onset and equally sudden offset originating in an abnormal or ectopic focus in the auricles junctional tissues or the ventricles Paroxysmal tachycardias may thus be regarded as due merely to a rapid succession of extrasystoles As such they depend on the same initiating factors The theoretical reasons for the maintenance of this focus as the pacemaker have been *touched upon in the preceding discussion concerning the genesis of extrasystolic arrhythmias* The idea that herein there is another possibility of a circus mechanism has been suggested in some theoretical discussions The mechanism begins sharply and stops abruptly often with an auricular and sometimes with a ventricular beat The rate rises from its normal level of about 80 to from 180 to 240 beats per minute and drops within one beat from the high rate to the previous normal rate of 80 or whatever it may have been

The types of paroxysmal tachycardia and the clinical manifestations and significance depend upon the focus of the mechanism disturbance *The ventricular type is by no means common and the junctional or* nodal type is quite rare while the auricular paroxysmal tachycardia is fairly frequent The point of origin determines in some way the type of the attack or at least some of its characteristics Commonest is the simple *auricular* paroxysmal tachycardia *This is the type that occurs off and on and lasts for short periods of minutes at first and gradually increases either in frequency or duration* There are some chronic sufferers who have had the disturbance for 20 to 30 years The few rare *junctional* paroxysmal tachycardias that have come under the author s care have lasted for long periods of time weeks and up to 18 months In one such instance the disturbance was observed to last for 1½ years

and then we lost track of the patient. The most serious form is *ventricular* paroxysmal tachycardia which usually lasts for hours or parts of a day and occasionally for several days. It is usually accompanied by very pronounced symptoms of serious heart disease, especially coronary sclerosis, thrombosis, and cardiac infarction

Paroxysmal tachycardia may, in rare instances, present a syndrome similar to that of cardiac infarction. There may be pain and collapse. Fever and leukocytosis, however, conclusive evidence of infarction, are rarely present. If the latter symptoms are present in paroxysmal tachycardia, it is not usually possible to make a diagnosis, but the electrocardiographic study may be very helpful, for it will determine the point of origin of the disturbance and give evidence of the conduction defects or changes that accompany cardiac infarction. In about two thirds of the cases of paroxysmal ventricular tachycardia other evidences of cardio vascular disease are present.

Symptoms and Complications: There are no premonitory symptoms for any of the varieties of paroxysmal tachycardia. Usually the onset is very abrupt and without any recognizable initiating factor. Occasionally, at the inception of the disturbance, there is a sensation of a momentary cardiac pain. The patient may not be conscious of the rapid rate as palpitation if the disturbance is regular, but again the overactivity may be quite disturbing and may be the patient's chief complaint. Occasionally giddiness, faintness, vertigo, weakness, exhaustion, dull pain. smothering and epigastric fullness, nausea, and vomiting may be present. In some instances, and especially in the ventricular type of paroxysmal tachycardia, there may be pulmonary edema, frothy blood tinged exudations and expectoration of large amounts of pink-stained sputum.

Patients during an attack may exhibit much anxiety, pallor, then grayness and cyanosis, coldness and clamminess. The neck vessels and the precordium throb rapidly and more or less violently. There is a rapid tictac embryocardia, but usually no murmurs or adventitious sounds are heard The pulse is small, rapid and regular. The heartbeat remains regular and rapid between 180 and 220 per minute usually: occasionally it drops as low as 140 and rises as high as 240 at the extremes In the auricular type, the rhythm is absolutely regular, as it is in the junctional or nodal type, but in the ventricular type of paroxysmal tachycardia, as pointed out by Levine, there is a slight irregularity revealed

by the fact that there are a few beats difference between minute to minute counts

Diagnosis Paroxysmal tachycardia along with fever and leukocytosis in the presence of pain, necessitates a careful examination for the other signs of a cardiac infarct Paroxysmal tachycardia may often arise during the progress of an operation or shortly afterward and is incorrectly diagnosed as acute cardiac dilatation The true state of affairs should be recognized for the good results of the operative procedures may be

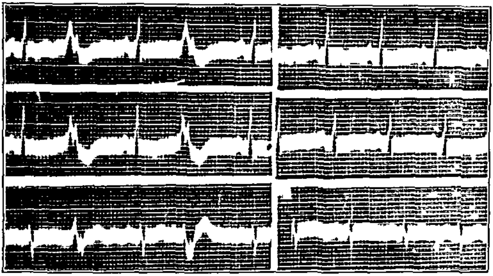


FIGURE 14 Digitalis bigeminy after diuresis

greatly jeopardized by the greatly decreased cardiac output minute volume and total blood flow Gangrene of a part may result from such a complication

The diagnosis must often be made from the history only, especially in the auricular type which at times lasts for only a few minutes and stops before a physician is reached and the opportunity of examination is afforded Here the suddenness of onset and offset, the regularity of the pulse and the equality of minute counts, together with a general lack of systemic disturbances due to the high heart rate suggests paroxysmal tachycardia of auricular origin An unusual physical or emotional strain as the possible precipitating factor is substantiating evidence

CASE XIV *Digitalis Bigeminy Following Diuresis* M B a negro longshoreman aged 38 was brought to the hospital *in extremis* very short of breath unable to lie down and waterlogged He had been able to

work up to about a week before admission There had however been some attacks of paroxysmal nocturnal dyspnea for some weeks previously and a swelling of the ankles at the end of the day and some upper abdominal distress and fullness had been noted during the preceding week

The physical examination revealed in addition to evidences of advanced congestive failure with engorgement of the neck veins and a cubital venous pressure of 30 cm of blood the signs of syphilitic aortic disease a throbbing of the carotid and subclavian arteries expansile pulsation of the aorta in the suprasternal notch an aortic systolic and a long high pitched diastolic murmur that was transmitted unchanged to the apex and the axilla The heart rate was rapid the rhythm was regular The heart was greatly enlarged the blood pressure was 190/60 in the left and 170/50 in the right brachial artery

The lungs bases were dull there was flatness on the right extending up to the angle of the scapula Coarse rales were present throughout the lower lobes The abdomen was enlarged the enlarged and tender liver border was felt four centimeters below the costal margin A fluid wave and shifting dullness of ascites was demonstrable Edema of the lower extremities extended up to the crests of the iliac

Digitalization by the rapid method was carried out at the rate of 0 3 Gm (1½ grains) three tablets of powdered leaf standardized digitalis every four hours for six doses After this 1½ grains were administered every six hours No effect on the edema was in evidence and so a half dose of mercupurin 1 cc was given intravenously A prompt diuresis resulted and apparently the consequent concentration of the digitalis glucoside had some toxic effect the patient became nauseated vomited and the bigeminy shown in Figure 11 appeared Atropine $\frac{1}{100}$ grain was given subcutaneously and the bigeminy cleared up

CASE XV *Paroxysmal Auricular Tachycardia with Syncopal Attacks Controlled by Psychotherapy and Potassium Iodide* G E O R aged 56 had some attacks of rapid heart action pounding and occasional fainting spells He had had a short mild attack in his youth as early as his 20th year These could usually be controlled by stretching out on the ground for a moment and taking a deep breath and holding it At about the age of 40 while he was under considerable nervous strain during the war he had recurrent attacks more frequent than usual and lasting longer or as long as 12 hours on two occasions These decreased sharply after the armistice and were rather infrequent for six or seven and possibly ten years after that After this time his responsibilities increased and the number of attacks increased particularly during the heavy summer business season

About a month before admission when under considerable stress he had a very severe attack He apparently fainted was given an opiate

injection, and did not recover consciousness for 12 hours. The narcotic, I believe, accounted for the delayed recovery He had apparently become quite cyanotic during the attack and this may have been exaggerated by

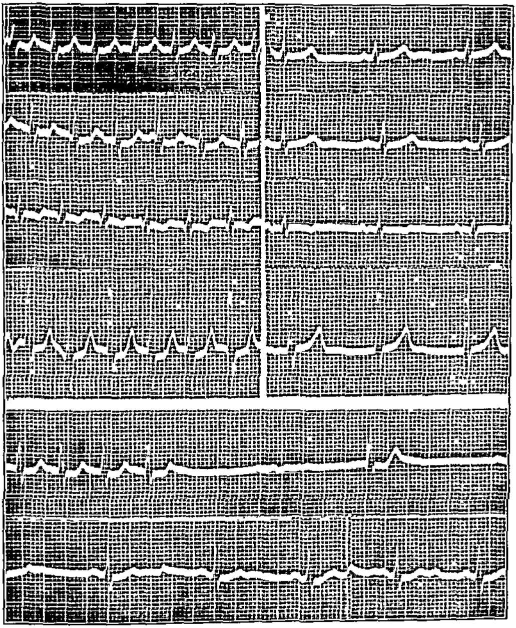


FIGURE 15 Paroxysmal auricular tachycardia stopped by carotid sinus pressure

the night light His physician had become alarmed and, unfortunately, had betrayed himself to his patient

The physician for the first time kept him in bed because he noted a continued rapid sinus tachycardia of 100 per minute. Aminophyllin was

administered and digitalization was accomplished. But, in spite of this therapy, the patient even with rest in bed got no better fast.

After a month's sojourn in bed the patient was brought to the J S. hospital. He was definitely quite anxious about his condition and his pulse was constantly rapid, 100 and 120 with frequent auricular premature contractions. His physician had tried to get him out of bed, but at the time he did so the attack was precipitated and the racing heart action was sufficient to cause the patient to faint. He had as many as 10 or 12 paroxysms a day. In a paroxysm his heart rate would rise to 160 per minute. His blood pressure, which averaged 136/77 in both brachial arteries at rest in bed while the cardiac mechanism was regular, would drop to 80/60 during a paroxysm. The heart was not definitely enlarged. Systolic murmurs were heard at the apex and in the aortic area. The aortic second sound was slightly accentuated. The heart rhythm was usually regular, but occasionally was interrupted by premature contractions. During the paroxysm it was always regular at a rate of 210 per minute and the sounds were of a tictac character. There were no definitely pathognomonic signs of heart disease.

The electrocardiograms confirmed the findings and showed that the auricular tachycardia could be stopped by carotid and sinus pressure, as shown in Figure 15 There was low voltage but no reliable evidences of myocardial damage in the electrocardiogram.

In view of the finding of persistent tachycardia, I was not absolutely certain that there was no myocardial disease. I felt, however, that there was a large psychogenic factor, particularly because I had noted that the patient was counting his own pulse. He had been digitalized, and aminophyllin in adequate amount had been given without any relief. Therefore, I concluded that his trouble was primarily psychogenic.

I advised him to get up each morning and remain up. He did this upon my order and fell out regularly each morning and had to be gathered up and put into a chair. After several mornings of similar experience, I questioned in my own mind my diagnosis, but I did not intimate this to the patient to whom I displayed only confidence in my decision. Finally, after the fifth day, the fainting spells did not recur on arising and the victory was accomplished. The patient had his confidence in himself reestablished, his fear of attacks was dispelled.

He was reassured and given potassium iodide in saturated solution, in the regular dosage of 15 drops three times a day. He has gotten along quite satisfactorily, carrying on his routine heavy duty and having nothing more than an occasional mild attack, usually during the time that he is under the most severe nervous strain. Under the most severe stress, phenobarbital is taken to ward off attacks. The attacks, as a rule, were easily controlled by stretching out horizontally for a few minutes or by pressure

tachycardia the outlook is less promising The few cases that have been seen were persistent for many months Under such stress the heart is bound to weaken Paroxysmal ventricular tachycardia is the most serious of the group, especially because of its frequent association with serious coronary damage The associated heart conditions therefore, determine in a large measure the prognosis of the mechanism change

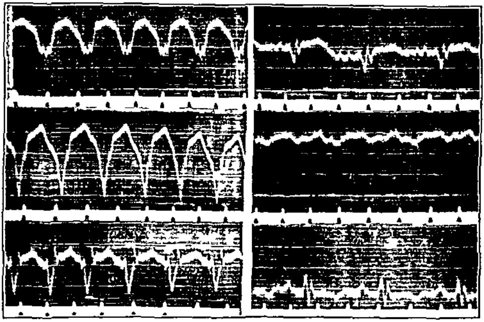


FIGURE 16

CASE XVI *Paroxysmal Ventricular Tachycardia Precipitated by Ephedrin and Stopped by Quinidine in a Patient with Coronary Thrombosis and Cardiac Infarction* S F a 70 year old contractor who had suffered from diabetes for a good many years had a *sudden attack of vomiting and pain high in the epigastric notch The pain spread up* substernally and over the precordium until it reached the neck shoulder, and left arm This excruciating pain lasted from 2 to 5 A M and seemed to come in waves of increasing *intensity He was partially relieved* by a quarter grain of morphine sulfate and 1/150 atropine given subcutaneously After about half an hour the dose was repeated He was thought to be moribund

On examination he was stuporous only semiconscious pallid with some cyanosis of the skin cold, and clammy His respirations were deep and labored and accompanied by *groans His body* temperature was subnormal He was in extreme shock of a secondary type

His pulse was found to be small thready rapid (100 per minute) it was noted to be irregular at times but regular most of the time His blood pressure was 80/60 The chest was emphysematous some dullness was elicited at the bases some coarse rales but predominately subcrepitatous pulmonary edema

The aorta was just palpable in the suprasternal notch The retromanubrial dullness was somewhat increased The cardiac dullness likewise was slightly greater than normal The apex impulse could not be definitely felt On auscultations the heart sounds were very faint with the exception of the aortic and pulmonary second sounds The typical and basal systolic murmur could be heard The abdomen was greatly distended. The liver and the spleen could not be felt There were no ascites and no edema of the extremities The electrocardiograms showed definite S T elevation in Leads I and II and developing negativity of T_1 and T_2

There was no fever at first but the next day the temperature rose to 100 The pulse increased slightly to 104 The blood pressure remained about the same 80/60 The extreme abdominal distention persisted There was also anuria A friction rub could be heard over the heart on the second day

Hot packs were put to the kidney region and in time urinary flow began Turpentine stupes and a rectal tube did very little good but theelin 10 000 units in oil intramuscularly seemed to stimulate the parasympathetics and relieve the ileus The leukocyte count rose to 12 500 the sedimentation rate was increased to 30 mm in an hour

His family physician became restless because of his low pressure and anuria and decided to give him ephedrin HCl ¾ grain every three hours After the second dose it was noticed that his pulse became weaker more thready and irregular The rate had almost doubled The blood pressure had actually dropped to 70/50 The electrocardiograms taken at this time showed very definite paroxysmal ventricular tachycardia The order for ephedrin was canceled and explanations were made to the family physician

The patient was tried out on a one grain dose of quinidine sulfate It was found that he was not sensitive to the drug and he took doses of five grains every hour until his mechanism disturbance was under control After the third hour of this dose the pulse slowed very definitely to about 100 per minute The electrocardiograms showed that the mechanism disorder was interrupted The blood pressure rose slightly as the pulse dropped to about 100 per minute

Treatment The treatment of paroxysmal tachycardia depends upon the type As stated before in about half of the cases of auricular tachy

cardia, prolonged paroxysms may be stopped by exerting pressure over the carotid sinus and compressing it steadily against the cervical transverse process on either side or by ocular pressure or other reflex vagus stimulation. The Valsalva and Mueller respiratory experiments, gagging and vomiting and the drinking of solutions in various unusual ways or positions, may often bring about a cessation through indirect or reflex vagus action. In the Valsalva experiment, the rise in blood pressure stimulates the receptors of afferent fibers in the aorta (Marey's) and carotid sinus (Hering's reflex), and the impulses thus aroused, upon arrival at the medulla, enhance the activity of the vagus nerve center and thus inhibit the heart. The other procedures may increase vagus action in an analogous reflex manner. Ipecac syrup, U. S. P. (fresh and potent), orally in 5 to 10 cc. (1 to 2 drams), and if ineffective repeated in an hour has been recently recommended by Sprague. Nausea and vomiting necessarily appear in 15 to 45 minutes after an effective dose. It may be necessary to increase the dose to the point of parasympathetic stimulation to get peripheral and central vagus action. Morphine sulfate usually stops an attack.

In order to abruptly stop the attacks, various powerful drugs have been used intravenously. Acetyl beta methylcholine in 0 02 to 0.04 Gm. (1/3 to 2/3 grain) subcutaneously is successful in 75 per cent of cases, particularly if followed by carotid sinus pressure. Digitalis as digifoline or digalen in 10 cc. (2½-dram) doses of five cat units intravenously will stop most severe paroxysms and is especially indicated if there are signs of myocardial insufficiency, and digitalization is usually a good prophylactic measure (Wilson and Wishart). Digilanid, in 4 cc. (1 dram) ampoules of 0.8 mg. (1/80 grain), or Digoxin in 1 mg. (1/65 grain) dosages are the safest emergency intravenous cardiac tonics. Strophanthus and ouabain are likewise considered to be effective, but are dangerous drugs in the presence of the high rate of paroxysmal tachycardia, for fatal ventricular fibrillation is not an infrequent complication.

A fatality during the intravenous injection of 1 Gm. (15 grains) of quinine dihydrochloride in a case of junctional tachycardia warrants caution in the intravenous use of powerful drugs in the presence of high heart rates.

Quinidine sulfate by mouth has been used successfully in many cases in doses of 0.3 or 0.5 Gm. (5 or 7½ grains), the average dose being 0.4

Gm (6 grains) every hour for eight doses Quinidine by mouth every four to eight hours seems to stop attacks in about two thirds of the cases and prevents a recurrence in a similar percentage

Magnesium sulfate in 20 per cent solution injected intravenously slowly for the first 5 cc (1¼ drams) then more rapidly 5 to 10 cc (1¼ to 2½ drams) is usually an effective method (*Zwillinger and St Fisher*)

Calcium chloride or gluconate intravenously in doses of 10 to 20 cc (2½ to 5 drams) of a ten per cent solution making a total of from 1 to 2 Gm (15 to 30 grains) of the drug will terminate 70 per cent of attacks (Wolfe and Bellett)

The calcium ion and its balance with potassium has been shown experimentally to have considerable effect and recently has prompted the prophylactic use of calcium by mouth The administration of vitamins A and D are given simultaneously in adequate amounts Calcium *preparations have been given by mouth in large amounts and in some* instances there has apparently resulted a decrease in frequency of attacks Calcium lactate in 1 Gm (15 grain) doses three times a day in tablet form should be used Parathyroid gland extract (parahormone) in 65 mg (1-grain) doses thrice daily apparently will stop attacks of paroxysmal tachycardia and prevent the recurrences

Potassium salts iodide chloride or acetate administered by mouth *in from 1 to 5 Gm (15 to 75 grains) doses will often serve to sharply* decrease the frequency of attacks of paroxysmal tachycardia

IX AURICULAR FLUTTER

Definition Auricular flutter is a disorder of auricular activity characterized by rapid regular abnormal auricular contractions and by ventricular systoles (usually regular) at a slower rate The rate of the auricular contractions ranges from 220 or slightly less to as much as 400 per minute The average is usually about 300 per minute The ventricular rate *is commonly one half the auricular rate because of the* presence of 2 1 auriculoventricular heart block but at times it is slower or irregular because of greater or varying degrees of heart block In some rare cases there is an absence of heart block *and the ventricular rate is* as rapid as the auricular rate (1 1 rhythm)

Varieties Auricular flutter may be (*a*) *paroxysmal* or (*b*) *established* Most commonly it is paroxysmal the arrhythmia lasting for a few minutes *hours rarely for months or years*

Pathogenesis: According to Lewis (1920), auricular flutter results from a change in the physiological condition of the auricular musculature which delays the rate at which the contraction passes through it. As a consequence, the wave of excitation and contraction, after traversing a part of the auricular musculature and returning to its point of origin, finds the latter no longer refractory, but irritable. In consequence, one contraction wave after another spreads along the same path in "circulatory rhythm." The path of the regular "circus contraction" is about the orifices of the great veins in the auricles; and impulses radiating from the "circus pathway" spread to all parts of the auricle and to the auriculoventricular node. If the course of the "circus contraction" is shortened, its rate increases; and, if it exceeds 500 per minute, it becomes irregular. When rapid and irregular, the condition is auricular fibrillation. Between *auricular flutter and fibrillation, there is a state which may be called* "flutter-fibrillation" ("impure flutter," "course fibrillation").

Clinically, auricular flutter may be considered as midway between paroxysmal auricular tachycardia and auricular fibrillation. However, the mechanism of auricular flutter differs entirely from that of paroxysmal auricular tachycardia, as evidenced by the electrocardiogram. Furthermore, as a rule, the auricular rate of paroxysmal auricular tachycardia is less than 200 or at most 250 per minute, while, with but rare exceptions, the auricular rate in auricular flutter is over 250 per minute (see section on ELECTROCARDIOGRAPHY).

Etiology: Pure auricular flutter is not extremely common. It is quite possible, however, that short paroxysms are frequently overlooked or are mistaken for paroxysmal tachycardia. It is occasionally found as a complication of mitral stenosis, thyrotoxicosis, hypertension, or coronary disease; it rarely occurs in perfectly healthy individuals without any other evidence of heart disease. Nervous excitement, sudden effort, surgical operation, or trauma may be precipitating factors. It is found *about three times more frequently among males than among females.* About three fourths of the cases occur after 50 years of age.

Pathology: *No known characteristic pathology* attends auricular flutter.

Symptoms and Complications: The commonest symptom is palpitation, which may be so severe as to give rise to marked nervous excitement When the ventricular rate is very rapid (200 or more per minute),

dizziness weakness faintness or actual syncope may result from impairment of circulatory efficiency Symptoms of congestive failure may be *coincident with* or may be induced by auricular flutter of long duration Congestive heart failure auricular thrombosis and embolism occur occasionally as complications but are less frequent than in auricular fibrillation

Diagnosis Usually an electrocardiogram is necessary to make certain the diagnosis of auricular flutter However the condition should be suspected in the presence of a *rapid regular heart action persisting in* spite of rest exercise and at times drug therapy particularly if there is other evidence of heart disease *Carotid sinus pressure merely slows* the ventricular rate momentarily in auricular flutter and fails to abolish the disorder This reaction differs from that of paroxysmal auricular tachycardia

Prognosis Auricular flutter is usually an annoying and more or less disabling condition but it is seldom dangerous Often the paroxysm lasts only a few minutes hours or days stopping as abruptly as it started or it may last for weeks or even years finally stopping spontaneously or changing to auricular fibrillation especially under full digitalization

Treatment Short paroxysms of auricular flutter lasting only a few minutes or several hours require no treatment other than reassurance and rest An ice bag to the precordium and a mild sedative such as *bromides or phenobarbital* may prove of benefit

CASE XVII *Auricular Flutter That was Changed to Auricular Fibrillation by Digitalization and Did Not Return to Normal Rhythm Even After Quinidine* Mrs L L housewife aged 47 presented herself because of an attack of rapid regular palpitation of the heart which was more disturbing than it had been previously The patient had had slight fainting attacks and somewhat similar heart action disturbances upon exertion or excitement for years She had always guarded herself and restricted her physical activities for she had been told that she had a heart affection *following rheumatic fever at the age of about 13* She had had no other serious illnesses in her life Her marital history was negative She had borne two children without any difficulty *Her family* history was significant in that her father had heart disease in the latter years of his life and had had irregular heart action and apparently died of heart failure at the age of 70

The physical examination was significant in that she showed the evidences of rheumatic mitral stenosis. She presented a high malar flush, and rapid regular movements of the A waves could be seen in her jugular veins which were slightly congested. Her heart rate was rapid, about 150 per minute. The rhythm was regular but would become irregular and the rate slower on pressure over the eyeballs or over the carotid bifurcations. Her heart was not definitely enlarged but just within the upper limits of normal size. A diastolic shock was felt in the pulmonary

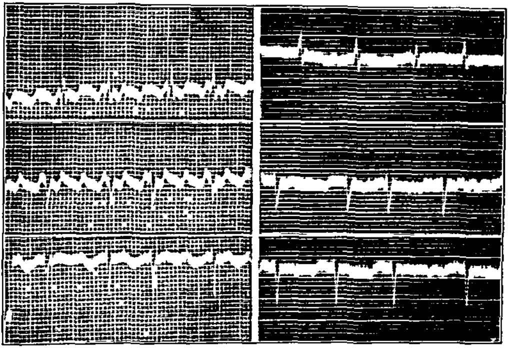


FIGURE 17. Auricular flutter digitalized to auricular fibrillation.

region and a systolic shock at the apex, along with a sharply localized diastolic thrill in the same region. A low rumbling diastolic murmur filling most of the phase was heard over the apex. There was a very slight, high pitched diastolic in the pulmonary area following a P_2 that was definitely accentuated.

Crepitant and subcrepitant rales were heard at the bases of the lungs and the chest and lungs were resonant throughout. There was a slight tenderness in the liver region, a slight (pitting) edema was present about the ankles.

Digitalization was undertaken and a dose of 4.5 grains, digitalis powdered leaf (three tablets of 1.5 grain each) was given every four hours for three doses for the first two days, then one tablet of 1.5 grain at six hour intervals for two days. The signs of myocardial failure, con

gestion, and rapid heart rate decreased but the rhythm became irregular Electrocardiograms showed auricular fibrillation (Fig 17).

After determining that she was not sensitive to quinidine sulfate a course of quinidine SO_4 five grains every hour for eight doses was given without, however, reestablishing normal sinus rhythm One daily dose of 1½ grains of digitalis P. I was sufficient to keep her heart rate at the optimum level of between 60 and 70 beats per minute

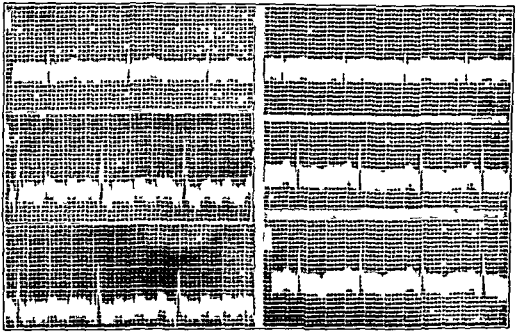


FIGURE 18 Auricular flutter changed to normal sinus rhythm

CASE XVIII *Auricular Flutter That Responded Directly to Quinidine Therapy* J J S, aged 68, complained of weakness and a rapid flut tering *in the neck in attacks He had lost a great deal of strength as well as weight* He had noted palpitation in his neck and ears on the slightest, even psychological exertion There was some dyspnea on exer tion after walking rapidly or slowly for ten blocks He was frequently on the verge of collapse He had had no pain in the precordium for several years His past history was negative except for sinusitis and possibly chronic lead absorption from a splattered lead bullet in his right spheno-maxillary region

The physical examination showed an emaciated old man with some cyanosis of his lips *There was a rapid movement in the jugular vein averaging about 300 beats per minute* However, the pulse rate was only 75 per minute His blood pressure varied from 110/80 to 135/92 The peripheral arteries were soft *His heart was slightly enlarged It extended*

11 cm. to the left of the midsternal line The heart action was regular and the heart sounds were of an extremely valvular quality. The mitral first sound was sharp and shocking at the apex as was also the aortic second sound. A faint systolic murmur was heard in the aortic area.

The lungs were clear. The abdomen was negative. The liver was not palpable or tender. The electrocardiograms showed auricular flutter and a four to one block The patient was put on *quinidine sulfate*, five grains every hour until his normal mechanism was restored after the third dose. The ventricular rate was more rapid after restoration than previously. The patient was, however, more comfortable.

When the paroxysm has lasted more than a few hours, digitalis should be given in doses of 0.2 Gm. (3 grains) of the powdered leaf, three or *four times daily, for several days, as indicated. If after several days the* ventricular rate has been reduced to normal but auricular flutter still persists, *digitalis should be continued in daily maintenance dosage.* At times, when auricular flutter changes to fibrillation under digitalis therapy, stopping the administration of the drug is followed by the return of normal rhythm. When normal rhythm is restored, further use of digitalis is not necessary. In about half the cases, digitalis therapy is successful; and in a few cases, when digitalis fails, quinidine sulfate proves successful. Digitalis should be given first trial; and then, if normal rhythm is not restored, a course of quinidine may be given. Quinidine sulfate, in doses of 0.2 Gm. (3 grains), two or three times a day, is at times of benefit in reducing the frequency of paroxysms.

Avoidance of fatigue, physical and mental overexertion, overeating, excessive use of alcohol, tea, coffee, and tobacco; infections; and congestive heart failure aid in the prevention of paroxysms of auricular flutter.

X. AURICULAR FIBRILLATION

Synonyms: Pulsus irregularis perpetuus; absolute or perpetual arrhythmia, delirium cordis, mitral pulse.

Definition: Auricular fibrillation is a cardiac arrhythmia, characterized by absolute irregularity of ventricular action and complete absence of normal auricular systole. Fundamentally, it is a disturbance of auricular origin, the walls of the auricles being the seat of fine rapid fibrillary contractions to some of which the ventricles respond in an irregular manner.

Varieties: Auricular fibrillation may be: (*a*) *Paroxysmal* or (*b*) *persistent*. It is usually the latter; and when once established, it tends to persist.

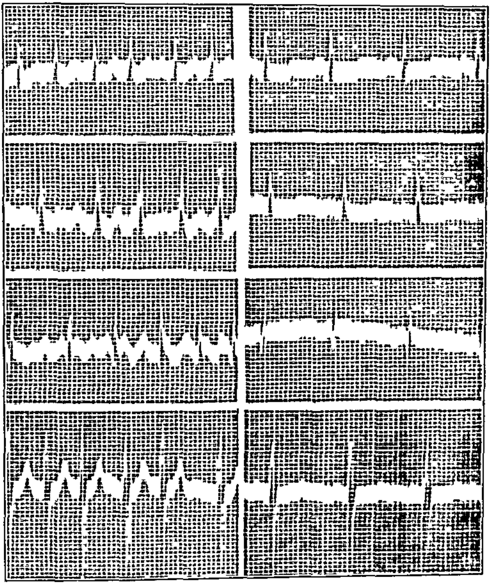


FIGURE 19 Auricular fibrillation cinchonized to normal sinus rhythm

CASE XIX *Paroxysmal Auricular Fibrillation Responding to Quinidine* Mrs H L P, aged 60, complained that she was frequently disturbed by attacks of rapid irregular heart action, which came on particularly when she was fatigued. She had had attacks for about three weeks. The first one followed a long automobile trip to Arkansas to visit

relatives It may be of some significance that during the trip it was pointed out to her that one brother had died suddenly of apparently heart disease at the age of 60 and three cousins had also died suddenly of similar afflictions It was added that she might do likewise The trip home through the suffocating heat of the Panhandle of Texas completely exhausted her

Two days after she returned home she recognized for the first time the attack as one of irregular heart action She called her physician who took an electrocardiogram and reassured her Then the attacks stopped There were however, frequent recurrences which continued up until the time she came to Galveston She had felt faint on one occasion when listening to a piano musical program She did not faint She had no definite shortness of breath and no pain over the heart. She had a slight edema of the left leg which recurred at times since 1918 when she had thrombophlebitis

Her past history is negative except for the thrombophlebitis which followed an operation for a fibroid during which also an ovary and tube were also removed along with the appendix She insists that she had been heart conscious for at least 20 years. She had been able to feel her heart beat against her chest while sitting in a chair or lying in bed Her tonsils were enlarged but she had never suffered from a sore throat She had scarlet fever at the age of three or four She was given large doses of calomel to the point of salivation from which she lost four teeth Her habits have been exemplary her marital history was negative, and irrelevant Her family history was good except for the sudden deaths of a brother and three cousins

The physical examination showed no reliable signs of heart disease other than the paroxysms of irregular heart action high rate with considerable apex speed 110 and 160 The retromanubrial dullness was at the upper limit of normal but the aortic second sound was not abnormally accentuated and no systolic murmur was heard at this time Nothing testified to the presence of aortic sclerosis There were paroxysms of auricular fibrillation the heart rate was frequently at 100 and would drop down into the eighties upon rest The blood pressure was 122/70 in the right and 120/68 in the left brachial artery The lungs were slightly hyperresonant The vital capacity was greatly reduced to 1600 cc which was about 50 per cent of normal There was a slight edema of the leg particularly the left leg Electrocardiograms confirmed the diagnosis of high-grade auricular fibrillation

The patient was put on quinidine sulfate two grains in a capsule given at half hour intervals until she had had a total of 10 or 20 grains. One five-grain tablet was administered at the next half hour In the next hour the heart rate was normal The dosage was maintained at five

grains twice a day for two days, and changed to one dose of three and one of five on the third and fourth days, the fifth day she was given one five-grain tablet a day which was divided, 2½ grains in the morning and 2½ grains of quinidine sulfate in the afternoon. She continued to remain free from attacks.

Pathogenesis: The mechanism of auricular fibrillation is quite similar to that of auricular flutter, except that the "circus mechanism" in auricular fibrillation is irregular and more rapid, being 400 to 600 per minute.

Etiology: Auricular fibrillation constitutes about 50 per cent of the cases of persistent arrhythmia of the human heart According to etiology, auricular fibrillation is commonly divided into (1) The rheumatic, and (2) the nonrheumatic (arteriosclerotic and miscellaneous) groups About 66 per cent of the cases are of rheumatic origin About two thirds of the cases of advanced mitral stenosis are complicated with auricular fibrillation. Auricular fibrillation is not infrequently associated with thyrotoxicosis. Comparatively rarely is it the result of syphilitic cardiovascular disease. Also, the combination of auricular fibrillation and angina pectoris is extremely rare; and subacute bacterial endocarditis and auricular fibrillation are rarely associated Occasionally it occurs in individuals, otherwise perfectly healthy, seemingly without heart disease It seems that possibly there is a nervous hypersensitiveness which predisposes to the arrhythmia At times factors, such as physical and mental overexertion, excessive use of tobacco, alcohol, tea and coffee, infectious diseases, trauma, and gas poisoning are responsible for the onset of paroxysmal or permanent auricular fibrillation. Males are affected about twice as frequently as females, possibly because of being subjected to greater strain. According to Stroud, Laplace and Reisinger, the average age of onset of auricular fibrillation due to rheumatic cardiovascular damage is 39 years, while the average age of onset in the arteriosclerotic (nonrheumatic) group is about 59 years

Pathology: No specific or characteristic anatomical or histological changes can be held accountable for auricular fibrillation.

Symptoms and Complications: Palpitation is the most characteristic symptom of auricular fibrillation. It is most annoying at the onset of permanent fibrillation or during paroxysms. When permanent and properly treated, auricular fibrillation exists at times without symptoms. Occa-

sionally dyspnea and precordial pain are complained of particularly when a marked psychic element is present or when myocardial failure develops When the heart is very rapid the individual may complain of weakness dizziness and faintness In many cases the ventricular (apex) rate is faster than *the radial pulse rate the difference being the pulse deficit* The apex rate may be as high as 160 per minute and the radial pulse rate as low as 90 and then with optimum digitalization both rates may become 70 the pulse deficit having disappeared In every case of auricular fibrillation it is extremely important to record not only the radial pulse rate but also the apex rate The blood pressure in auricular fibrillation may be normal high or low

Heart failure forms the chief complication of auricular fibrillation Another often serious and at times fatal complication is *embolism* into the cerebral splenic renal or peripheral circulation The emboli arise from thrombi that form as the result of stagnation of the blood in the dilated noncontracting fibrillating auricles

Diagnosis A conspicuous arrhythmia that persists when the heart rate is increased to 140 per minute is auricular fibrillation Other types of disturbance of the heart s rhythm vanish as the heart rate is elevated to 120 to 140 per minute The rule may fail in rare instances of short paroxysms of auricular tachycardia and flutter

Electrocardiography is of great value in confirming the diagnosis of auricular fibrillation The typical electrocardiogram is characterized by total irregularity of ventricular complexes an absence of P waves the presence of small rapid undulations (*f* waves) and not infrequently variations in the amplitude of the R wave from cycle to cycle

Prognosis In the absence of serious myocardial disease auricular fibrillation of paroxysmal or chronic form may cause very little discomfort if the ventricular rate is kept within normal range Quinidine therapy will establish normal sinus rhythm in some individuals others when kept digitalized are able to enjoy active lives for 20 or more years Because of the danger of myocardial failure the tachycardia is more serious than the irregularity *per se* According to Cookson the expectation of life in auricular fibrillation is greater in the arteriosclerotic (non rheumatic) group than in the rheumatic group In 23 rheumatic cases in which the age of onset of fibrillation was between 12 and 17 years the average duration of life was 10 months while in 16 cases in which

the age of onset was between 28 and 38 years, the average duration of life was 6.5 years. In very rare cases, death occurs suddenly, presumably due to ventricular fibrillation or cerebral embolism.

CASE XX. *High grade Auricular Fibrillation That Was Over digitalized:* Mrs. J. C., a Southern lady of 70 summers, complained of *irregular heart action, shortness of breath, weakness, and headaches. She*

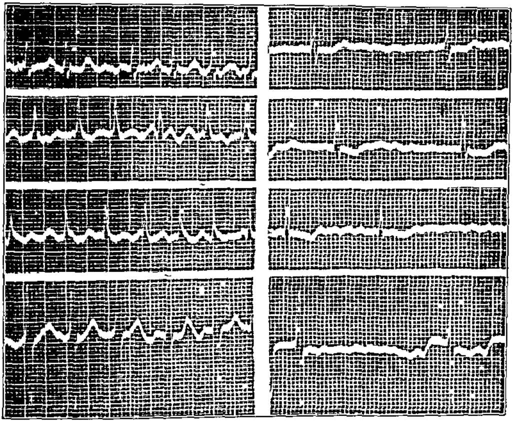


FIGURE 20. Auricular fibrillation overdigitalized.

began to have trouble when she was in the mountains of Colorado in the summer of 1938. She went from there to the Ozarks, at which altitude she was more comfortable, but she had peculiar cerebral episodes, difficulty in breathing, and in using her right hand which lasted for about three hours. After this attack headache was more severe and occurred more frequently. *She had been found allergic* to milk and milk products and had refrained from the use of such for 18 months, but had begun again some weeks before her present illness began. A rheumatic infection 20 years and sciatica about 30 years, previously cleared up after she had had infected teeth removed. Otherwise her past history, marital history,

and family history were entirely negative, except for the fact that her father died at 71 years of age of "stroke."

The examination showed a woman who looked much younger than her given age. She took a deep sighing breath about every sixth inspiration. There was no engorgement of the neck veins. The retromanubrial dullness measured 6 cm. The heart was at the upper limit of normal size, extending 3.5 cm. to the right in the fourth interspace and 12.5 cm. to the left in the fifth interspace. The heart action was absolutely irregular and very rapid, averaging about 160 beats per minute. There were no abnormalities found in the close examination of the heart. The radial pulse likewise was quite irregular, but only averaged about 100 per minute, which showed a definite loss of 50 or 60 beats per minute. There was no sclerosis of the peripheral vessels. The blood pressure was low, 130 to 110 systolic and 80 to 70 diastolic. The lungs were slightly hyperresonant but clear throughout. There was no tenderness in the abdomen. The liver was not engorged, nor palpable. There was no edema of the extremities.

The electrocardiograms were taken which confirmed the diagnosis of a high grade auricular fibrillation.

The patient was sent to her physician with the orders that she be rapidly digitalized at the rate of 1½ grains of digitalis P. L. six times a day for three to five days and then three times a day for a few days. She returned 18 days later quite upset. Another electrocardiogram was taken. The heart rate was found to be in the neighborhood of 50 per minute. She had a very severe acute diarrhea. There were visual disturbances which colored most objects tan or brown, gave the skin a bluish, cyanotic color. This disturbed her considerably. She had taken 27 grains of a good grade of digitalis powdered leaf in capsules, during the first three days, and 4.5 grains a day for the next 15 days, for a total of 85 grains in 18 days. Of course, the dosage should have been cut down to 1.5 grains a day as soon as her heart rate dropped to the rate of 70 on the third day. This optimal heart rate probably could have been maintained on perhaps 1.5 grain a day. In view of the apparent digitalis poisoning the drug was suspended for ten days. She was then put on digilanid 0.3 mg. per day which maintained her at a low rate and in spite of discontinuance of it a day or two a week. She again began to have symptoms which were relieved after she stopped the use of the drug for a few days. The pulse rate has remained between 50 and 70 per minute.

Treatment: Absolute rest and full digitalization are indicated in cases of auricular fibrillation of high grade with congestive failure. In the absence of serious myocardial disease, congestive failure, and the history of embolism, quinidine sulfate may be administered. A paroxysm

of auricular fibrillation which has been present for more than two or three hours can often be arrested with quinidine. Digitalis should not be prescribed in paroxysms of short duration because of its slower action and because it may prolong the attack. However, if quinidine proves ineffective, digitalis should be used, especially if congestive failure supervenes.

Bromides (1 Gm—15 grains—three times a day) or phenobarbital (0.016 to 0.032 Gm—¼ to ½ grain—three times a day) prove useful in allaying restlessness. An ice bag locally is of value in relieving precordial discomfort. Occasionally, codeine sulfate (0.016 to 0.032 Gm—¼ to ½ grain—by *mouth or hypodermically), or morphine sulfate (0.01 to* 0.016 Gm.—⅙ to ¼ grain—hypodermically) is necessary to relieve marked restlessness, palpitation, or precordial pain. Reassurance is of great importance in every case of auricular fibrillation.

In all cases of *auricular fibrillation,* physical and mental overexertion, overeating, fatigue, excessive use of tobacco, alcohol, tea and coffee, and infectious diseases should be avoided.

Focal infections should be corrected as far as possible. Surgical operations and anesthesia should not be withheld when obviously indicated. With proper preoperative treatment, patients with advanced heart disease stand surgical procedure quite well.

When *thyrotoxicosis is present,* thyroidectomy should be considered and is usually necessary to correct the cardiac disorder. In such cases the administration of Lugol's solution (five to ten drops, three times a day) for a week before operation has a quieting effect on the heart action.

XI. DISORDERS OF IMPULSE CONDUCTION

1. Heart Block: Conductivity is one of the primary physiological properties of heart muscle. Impulses are rhythmically generated in the sinoauricular node and then spread out, more or less radially, through the auricular muscle, being propagated from muscle cell to muscle cell, at a rate of about 1000 mm. per second. There are apparently no specialized pathways in the auricular muscle. Arrived at the A-V node, the progress of the wave of excitation (and contraction) is slowed, the velocity of conduction through the node being very low. Passing downward through the A-V node and bundle, the impulse accelerates as it enters the large, glycogen rich fibers of the bundle branches and their arborizations, the subendocardial Purkinje network, the rate of propagation rising to

(2) Pathological Physiology of Heart Block: In general, it may be safely stated that only in the higher grades of heart block, such as 2:1 partial or complete heart block, is there enough mechanical disturbance due to the excessive slowing of the ventricle to produce symptoms resulting from the decreased minute volume. Some patients with congenital heart block, or with rheumatic heart block and little other rheumatic heart disease, may continue unhampered through life. Congestive failure is rare in spite of the associated myocardial conditions, probably because the prolonged diastolic period of the slow heart permits sufficiently complete recovery and oxygenation, and thus the extra strain that the block puts on the heart, a strain which would otherwise be a precipitating factor, is compensated.

(3) Symptoms of Low Grade H. B. as simple defective auriculoventricular conduction are usually *nil*. If any are present they may be considered to be due to the effect of the disease process on other parts of the heart. Complications usually do not ensue, but eventually most cases advance to higher grades of heart block.

(4) Symptoms of the High Grade H. B.: In the higher grade symptoms appear weakness, fatigability, precordial pain, and abdominal pain simulating gastric ulcer are usual complaints. Giddiness, vertigo, and syncopal attacks are the common symptoms in elderly individuals, especially in those with cerebral arteriosclerosis as well as with cardiac sclerosis The sensory symptoms of the dropped beat may frequently be similar to those that are present during and after the postextrasystolic pause and its subsequent contraction.

(5) Diagnosis: This depends upon the use of graphic methods, especially electrocardiograms, in which the increased P-R interval is easily recognized. The condition may be suspected from the presence of the presystolic gallop rhythm, the result of an abnormally wide separation of auricular and ventricular activity and sounds. Normally, the systoles in both auricles and both ventricles come within 0.18 second of each other and produce sounds which blend in forming the first heart sounds. With the increase of the conduction interval between the two systoles, the sound of the auricular activity may split off and be heard as a slight presystolic element. As the interval increases, the auricular sound may be heard nearer the second sound, thus producing the *protodiastolic* gallop rhythm.

(6) PROGNOSIS: At best, the prognosis must be guarded, for in the presence of such a sign of definite heart disease, the changes of rheumatic, syphilitic, or arteriosclerotic disease in other parts of the heart may lead sooner or later to a fatal issue. Occasionally, however, the patient may have conduction pathway damage, and relatively little other myocardial disease. In such cases, and the very rare ones that have congenital conduction defects, the outlook may be relatively good, but there is no way of foretelling this with certainty.

(7) TREATMENT: This depends upon the symptoms, the type and extent of the heart disease, and the degree of heart block that is present. The asymptomatic type calls for the directing of therapy against the etiological factor, whether it be local, rheumatic nodules or syphilitic infiltration, or vascular changes. There is often a response to salicylates and iodides. Even arteriosclerotic processes and local circulatory disturbances are in a measure amenable to treatment with iodides, theophylline and nitrites.

Removal of vagal influence can be accomplished with tincture of belladonna in 1 cc. (16-minim) doses, atropine in 1 to 2 mg ($1/65$ to $1/30$ grain) doses, or homatropine bromethylate (novatropine) in 0.0065 Gm. ($1/10$ grain) *doses to the point of tolerance.*

Digitalis, through its vagotonic effects, usually increases the degree of block and may seriously *embarrass an already impaired circulation by* decreasing the number of ventricular beats per minute. The slowing may, however, afford a sufficient diastolic interval for almost complete oxygenation and thereby actually be beneficial. In partial heart block with frequent and disturbing intervening of complete block, it is usually distinctly advantageous to digitalize the patient and put him into complete and permanent block with a regular idioventricular rhythm at the rate of 40 per minute.

CASE XXI: *Two to One Heart Block Relieved by Atropine:* Mrs W R, aged 55, a housewife, had no symptoms referable to her heart until after she had had a septic sore throat in the fall of 1937. Her sore throat was apparently very severe with very high fever. Smears and cultures were taken of her throat which showed short chained diplococci but no diphtheria bacilli were found. The tonsils became ulcerated and drained into the neck glands. After several days of local treatment, she was given sulfanilamide, 15 grains, every four hours for six doses each day for two days. At the end of this time the temperature dropped below the normal

level It was noticed that her pulse rate likewise decreased very sharply to about 40 per minute. Her nail beds and her mucous membranes were somewhat cyanotic. She noted some giddiness and a slight shortness of the breath

The electrocardiograms showed a partial two to one auriculoventricular heart block An injection of $\frac{1}{75}$ Gm of atropine sulfate was administered Her pulse rate promptly rose as is shown in the electrocardiograms to 120 per minute In just a few days, however, the ventricular and auricular rates slowed down to a level of 75 and remained so All

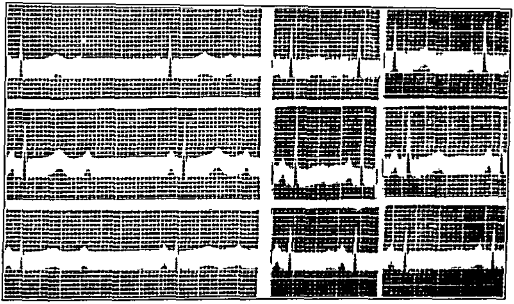


FIGURE 21 Partial heart block relieved by atropine

symptoms disappeared and the cultures were reported negative for diphtheria This patient had had in her past history diphtheria for which she had been given antitoxin This was, I believe, in 1910 It is *possible that this previous diphtheria had produced, as it frequently does,* slight changes in the conduction pathways which persisted in a block which was caused in the presence of another severe throat infection

(d) Complete Heart Block The conduction to the ventricle may gradually become so poor that only 1 out of 3, 4, 5 or 6 auricular impulses goes through to the ventricle Finally, a point is reached when no beats are transmitted and there is a state of complete dissociation or *complete heart block* Under such conditions the auricle beats on at its own rate and the ventricle is activated by its own pacemaker at a slow, regular independent rhythm Idioventricular foci are of considerably slower

heart rate remains at 40 or less, regardless of exercise, amyl nitrite, or atropine.

Prognosis of all types of heart block is serious The higher the grade of block, the more serious the prognosis Death may occur suddenly in convulsive syncope or with cardiac pain, and much more uncommonly in congestive failure with edema.

CASE XXII *Heart Block with Adams Stokes Attacks Relieved by Atropine and Ephedrine* J W, aged 73, a retired merchant, was being subjected to a prostatectomy When near the end of the operation he

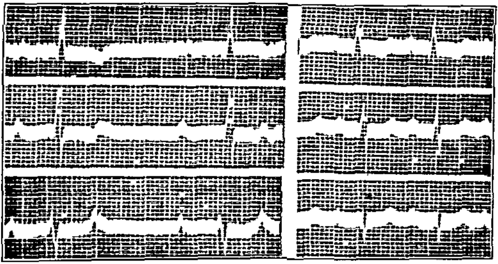


FIGURE 22. Adams Stokes disease relieved by atropine and ephedrine

collapsed, became deeply cyanotic His heart had stopped beating, the neck veins became engorged As emergency treatment he was given thyroxin $\frac{1}{120}$ grain and epinephrine hydrochloride $\frac{1}{1000}$, three minims, into the jugular vein and he was put into an upright position Sharp blows were directed against the precordial area At the same time atropine sulfate was given at the rate of $\frac{1}{100}$ grain every five minutes until five doses had been given Immediately after the pulse returned the patient became quite flushed, the operation was completed and he was taken to his room

The electrocardiograms taken directly after the operation showed a normal mechanism with an increased rate of 120 per minute. Nothing further was done throughout the day. After the atropine effects had worn off the patient began again to have a low pulse rate. It dropped to 60 and then to 30 beats per minute The electrocardiograms taken at that time showed two to one and four to one or complete heart block

It was of interest to learn that a brother had died in an Adams-Stokes attack a few years previously

He was put on regular dosage of atropine, $\frac{1}{100}$ grain, every three hours The pulse rate gradually rose to the level of 90 or 100 and remained there as long as the atropine was continued The heart block would reappear upon the suspension of the atropinization and on one occasion a short attack of convulsive syncope, an Adams Stokes seizure intervened Ephedrine hydrochloride, $\frac{3}{8}$ grain, three times a day instead of the atropine sulfate was successful in preventing recurrences of the attack Barium chloride in $\frac{1}{3}$ grain doses twice daily failed to maintain the normal heart rate

The physical examination showed a heart outline that was at the upper limit of normal, a slight increase in the retromanubrial dullness, a loud systolic aortic murmur and an accentuated aortic second sound suggested the presence of aortic arteriosclerosis in this area There was a normal blood pressure and evidences of sclerosis of the peripheral arteries He did well as long as he remained on atropine or ephedrine but atropine caused a dryness of his mouth and ephedrine made him nervous The treatment, however, at any time that he was having difficulties was ephedrine or atropine He got along quite satisfactorily for several months He developed an appendicitis and peritonitis for which he was operated upon again and from which he failed to recover, although his heart rate remained normal throughout There was no suggestion of a recurrence of the previous trouble As the atropine had been used and had prevented the reestablishment of the heart block We would now try paredrine hydrobromide in 20 mg doses two or three times a day to prevent the heart stoppage, but we would probably use atropine sulfate too

Treatment In Adams Stokes attacks there is necessity for medication *which will stimulate and keep irritable the ventricular pacemaker* In an emergency, epinephrine hydrochloride in a dose of 0 25 to 0 5 cc (4 to 8 minims) of a 1 1000 solution may be administered intravenously *into the jugular, or even intracardiacly* Barium chloride or ephedrine hydrochloride or paradrine hydrobromide, each in 50 mg ($\frac{3}{4}$ grain) doses by mouth may be useful in preventing ventricular standstill

(*f*) *Bundle Branch Block*· Synonyms Complete intraventricular conduction defect, asynchronous action of the two ventricles

Definition Bundle branch block is a *serious cardiac mechanism dis* turbance, the result of interference with the conduction of the excitatory process below the bifurcation of the auriculoventricular bundle

The bundle branch block may be complete or incomplete, rarely partial, and may occur in either branch. There is thus a delay in the excitation of the affected ventricle until the impulse spreads to it through the muscle from the unblocked bundle branch.

Diagnosis: The diagnosis is made with certainty only by the characteristic electrocardiographic findings. There may be a prolonged muffled blurted first heart sound. Sometimes such a great separation of the sound elements occur that the part of the first sound caused by the contraction of the promptly activated ventricle appears to come in late diastole, truly in presystole, and thus simulates the rumble of mitral stenosis. Along with the suggestive changes in the first heart sound, reduplication of the second at the base and a double apical thrust have been considered as almost diagnostic of the condition. Unfortunately, not more than half of the cases that are discovered by the electrocardiographic findings (the broad Q-R S interval of 0.12 to 0.16 second with the T waves oppositely directed to the main deflection) show these clinical evidences when subsequently examined.

CASE XXIII· *Acute and Recurrent Bundle Branch Block Along with Acute Rheumatic Carditis:* L. H., aged 28, recently married, began to have heart trouble, fever, and painful joints, following the cessation of her menses. She described a typical migratory arthritis of acute rheumatic fever. She soon became conscious of a dull pain in the region of her heart and a peculiar rumbling palpitation that had persisted.

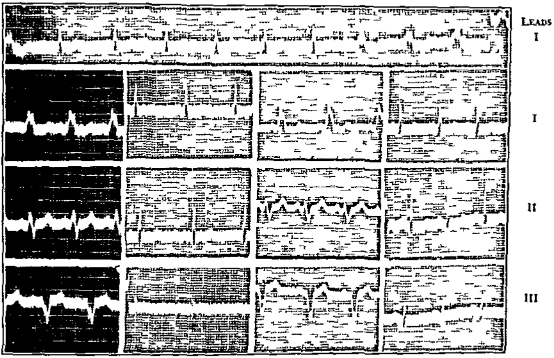
Upon physical examination she was found to have a low grade fever, moderately rapid pulse, normal blood pressure. Her heart was not enlarged. The apex beat, however, was somewhat diffuse and apparently double humped The retromanubrial dullness seemed to be at the upper limit of normal. There was heard in the base upon auscultation a high pitched diastolic murmur and over the conus arteriosus there was a to and fro leathery friction rub, and at the apex a systolic murmur. The chest and abdomen were otherwise negative, except that the obstetrician thought that she was two months' pregnant.

Diagnosis of an acute rheumatic aortic and mitral valvulitis and pericarditis and pregnancy were made. Electrocardiograms showed a very definite complete bundle block of the usual type as shown in the Figure 23 *A*.

She was put to bed and given sodium salicylate in daily 24-hour rations of one grain per pound of body weight in equally divided dosage every four hours After her fever subsided she was given half the dose for a period of two weeks, then a quarter of the dose for another two months.

She was continued on one-eighth the dosage, for a period of five months During this time her condition improved considerably Her rheumatic carditis apparently cleared up and her pregnancy progressed The pericardial friction rub gradually disappeared the systolic murmur became somewhat louder, the aortic diastolic persisted The electrocardiogram, however, showed a very definite change back to normal intraventricular conduction time

She was kept in bed until the eighth month and as her intraventricular conduction was normal (Fig 23 *B*) Dr E L King did a low cesarean



A On admission *B* Just precesarean *C* Postcesarean *D* Just before sterilization

FIGURE 23 Transient bundle branch block

section and delivered a living child However, after the cesarean section was done, the bundle branch block was found to return (Fig 23 *C*) She was put on bed rest treatment for another two weeks, and when the intraventricular conduction defect disappeared (Fig 23 *D*) she subjected to a sterilization operation The bundle branch block was again in evidence and continued during her postoperative period She was allowed to leave the hospital with her babe and continued small daily rations of sodium salicylate for a year She was advised to restrict her activities moderately She was able to carry on, however, satisfactorily

Prognosis: In itself, this is serious, aside from the fact that the condition is evidence of serious myocardial damage. Slight provocation, such as a minor operation even under local anesthesia, may be sufficient to precipitate fatal ventricular fibrillation.

The condition is occasionally temporary or transient.

Treatment: This is similar to that of other types of heart block, especially those of arteriosclerotic origin, with emphasis on the use of iodides and coronary vasodilators.

(*g*) *Alternation: Synonyms: Pulsus alternans; alternation of the* pulse; alternation of the heartbeat; alternation of the heart mechanism.

Definition: Alternation is a palpable weakness of every other regularly placed heartbeat and pulse wave, resulting apparently from partial contraction of the ventricle with each alternate systole. The phenomenon is detectable not only in palpation of the pulse, but also in the taking of the blood pressure, and occasionally also in auscultation of the heart, but rarely in the electrocardiogram.

The important fact to be remembered is that the contractions of the heart are equally spaced. The apex impulses occur regularly.

The pathogenesis of the condition is quite obscure. The theory most generally accepted is that because of circulatory disturbances, the ventricular muscle recovers unduly slowly, so that there is apparently a division of cardiac musculature into three unequal masses. *A*, responds during each beat, *B*, which is larger than *C*, during every other beat; and *C*, during those alternate beats when *B* fails. The beat, *A* + *B*, is stronger than *A* + *C* because *B* is larger than *C*. The group of cells, *B*, that has just responded during one beat, having a slow recovery, is in the refractory period when the alternate impulse comes and activates the smaller muscle mass; but by the time the next impulse arrives, the larger mass is out of the refractory state and is ready to contract, while the smaller mass, *C*, that responded is refractory.

Conduction disturbances in intracardiac impulse propagation may likewise accompany these changing refractory states.

Anatomically, there is nothing that can be recognized as pathognomonic of the condition. The hearts that during life exhibited this phenomenon, however, usually show extensive degenerative changes which are frequently of arteriosclerotic coronary origin, with secondary nutritional degenerative chemical changes in the myocardium.

The patients are usually over 50 years of age and, as a rule, present evidence of hypertensive heart disease.

Sudden strain on the heart, such as periods of rapid heart action, whether due to paroxysmal tachycardia, auricular flutter, or auricular fibrillation, may give rise to alternation. Instead of allowing time for adequate oxidation and recovery in the all too short diastolic period, the already embarrassed heart muscle, driven at a rapid rate, recovers abnormally slowly from its fatigue and its refractory state.

Symptoms: There are no symptoms that can be referred directly to alternation. The condition is usually associated with myocardial insufficiency, the serious symptoms of which are the cardinal symptoms of heart disease present: *Dyspnea, edema, congestion and pain.*

Diagnosis: Alternation is usually suggested by careful palpation of the pulse; when the latter is evenly spaced, alternate weak and strong beats are detected. The condition should be looked for in all patients with chronic cardiovascular disease. It is a very simple matter to confirm a suspicion of its presence by taking the blood pressure and carefully determining the two systolic levels, one at which only half the beats come through and the other 10 or 20 mm. lower down, at which all the pulse waves are transmitted.

A tracing of the pulse wave will clearly show the alternation in amplitude. An electrocardiogram will differentiate alternation from the rare instances of bigeminy in which the premature contraction following every normal beat comes so late in diastole that the difference between the two intervals is too slight to be detected by any ordinary sense of touch or of hearing.

Prognosis: The prognostic significance depends upon some of the concomitant findings. Immediately after a fatiguing episode of paroxysmal tachycardia, flutter or fibrillation, or premature contractions, alternation is not nearly so ominous as when it is found in patients with a slow, regular cardiac mechanism under which circumstances it spells imminent dissolution. In youth and early adult life the condition is probably less significant than when it appears after middle age.

Treatment: This should be directed toward improving the general coronary circulation, and incidentally the chemical condition of the myocardium.

CASE XXIV *Obesity Hypertensive Arteriolar Disease with Myocardial Weakness and Pulsus Alternans or Alternation* E. G a middle aged executive had had as his nemesis a voracious appetite for many years He carried his excessive body weight of 350 pounds until at the age of 35 he collapsed had some pulmonary edema bloody expectoration and profound exhaustion It was noted that there was conspicuous alternation in his pulse Two definite systolic blood pressures one of 220/110

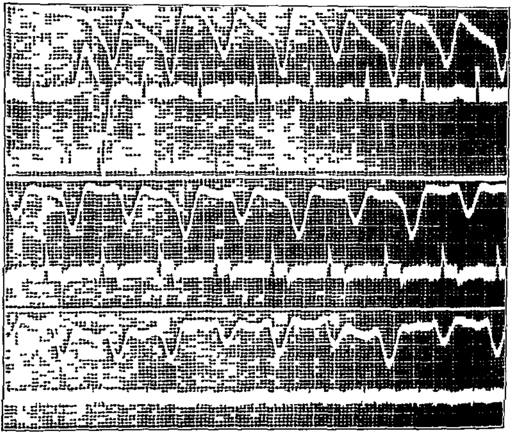


FIGURE 21 Pulsus alternans

and one of 180/110 were recorded in each brachial artery His heart was definitely enlarged a conspicuous gallop rhythm an accentuation of the aortic second sound and a faint aortic and moderately loud mitral systolic murmurs were heard The neck veins were slightly engorged The bases of the lungs were slightly dull and subcrepitant rales were quite numerous The liver edge was palpable and tender Electrocardiograms showed slight changes in his T wave in Leads I and II and some suggestive evidences of myocardial damage but no pathognomonic signs of cardiac

infarction of acute coronary major artery occlusion bundle branch block bigeminy, or alternation of the voltage of the R waves

At absolute rest in bed his caloric intake was sharply restricted and he lost 100 pounds of weight and was very much improved The alternations disappeared He could not keep his weight 250 pounds and his blood pressure remained in the neighborhood of 190/110 With moderate restrictions in the amount of physical exertion that he did and the amount of food that he consumed he was able to carry on for five years An acute sinusitis precipitated another attack of congestive failure with alternation and edema from which he failed to recover

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